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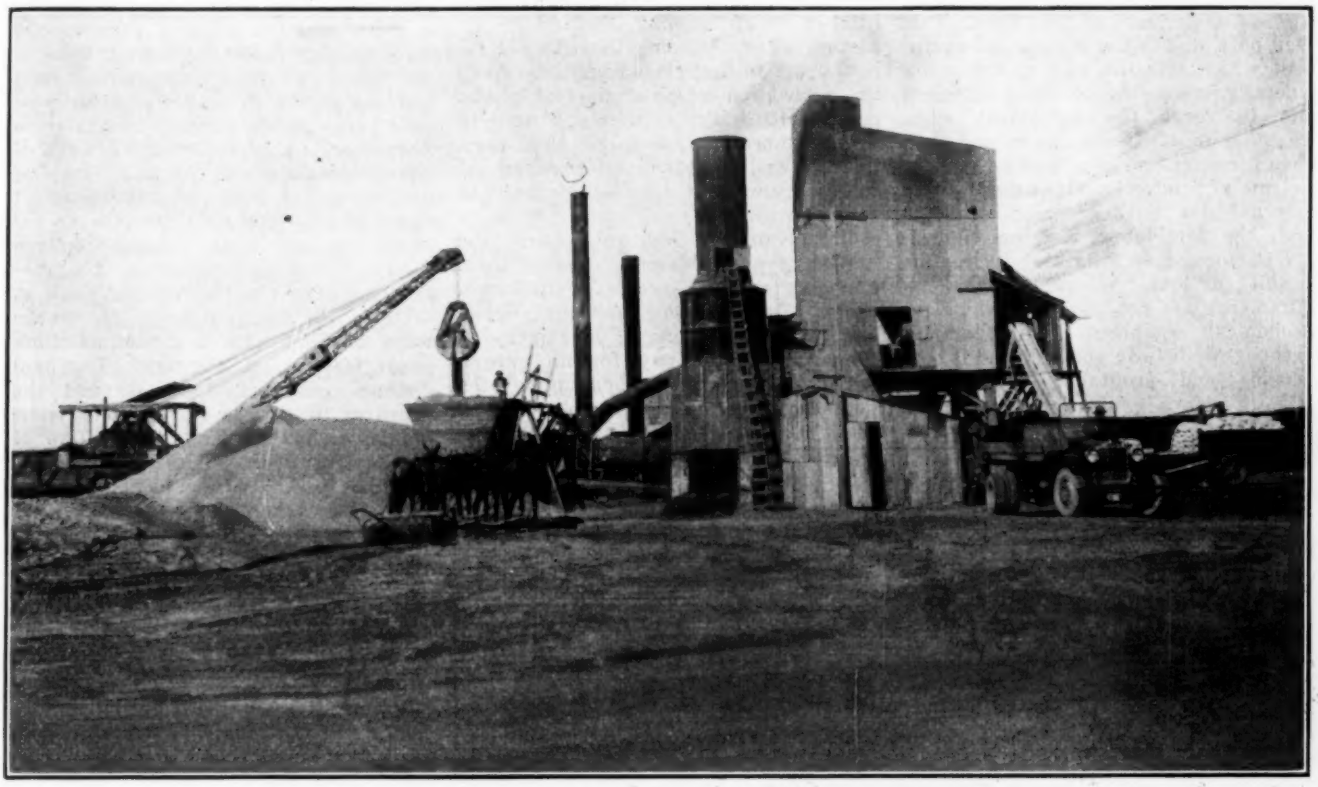

Road Paving Work Involves the Proper Coordination and Synchronization of a Large Number of Separate Operations in Order to Maintain a Profitable Rate of Production

Economic Effects of Management in Highway Grading Work

How to Increase Production at Decreased Unit Costs

By C. F. ROGERS

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THE Division of Management of the Bureau of Public Roads has been engaged for the past four or five years in an intensive study of highway construction methods and costs. We feel that we have made fair progress. The project is a cooperative one in which the bureau, the contractor and the state highway officials are all concerned. We only make a study of this sort when we have the consent of the contractor on the job being studied and of the state highway officials under whose jurisdiction it is being built. Our object is the stimulation of production at decreased unit costs. It is our hope that our work has been profitable to some of you, and it is our hope that as the years come and go and as we become better acquainted with each other, the benefits accruing will constantly be augmented.

Results of Poor Management.—In the prosecution of your work you need men, machines and materials, but unless you have in addition the ability to efficiently employ these, the Demon Waste will become paramount and dissipate your profits. Of all the causes contributing to contract losses on the jobs we have studied, poor management is the chiefest. Consequently, if the contractor is himself unable to spend practically all of his time directing his contract job, he should spare no effort to place on it a capable superintendent or general foreman. You should hire for that position the best man you can find and pay him enough to secure his undivided loyalty and interest. It will probably pay you to give him a bonus, the amount depending upon his accomplishments above a certain fixed task. Does it not seem reasonable that if a man can get an increase in compensation provided he turns out more work, he will do the utmost of which he is capable? If he does not work out in this manner evidently the man has but little ability or but little ambition, and in either case the sooner you find this out and make a change the better for the profit side of your ledger.

30 Per Cent Lost Time for Average

Laborer.—On a great many jobs we have also made studies of the personnel, and I think you will be surprised to know that we find in most lines of road construction work that the average laborer does not actually work over about 70 per cent of the time for which he is paid. We find some who work as little as 40 per cent of this time. This is, in part, due to the mechanical equipment which sets the pace and you are generally compelled to have sufficient men to serve the equipment when operation is at its maximum and then when for some one of a hundred reasons the rate of production slows down, these men are not fully occupied. But, in part, the low labor working time is due to some men's natural inclination to shirk or loaf. Where the labor requirements are not rigidly fixed by the mechanical equipment and operation methods, we believe you will find it both possible and profitable to ascertain those of your organization who occupy, say, the lower third in ability to produce, and replace them as rapidly as you can with better men. If you will adopt this practice it will pay you. Otherwise the more industrious of your men cannot but come to feel that additional industry on their part is only helping to fill the pay envelopes of the drones, and the result is sure to be more or less of a brake on the progress of the job. It will be to your advantage to study the individuals on each job you have in progress. Men who produce far below the average are as detrimental on any job as badly worn or antiquated machines. It is quite important that you give due consideration to the conditions under which men work, as these have considerable influence upon their loyalty and their willingness and capacity to produce.

No Wonder This Contractor Claimed He Lost Money on His Shoulder Construction

Retaining Efficient Workmen.—The size of the organization, that you may retain on the straight time payroll in periods of enforced idleness, should be determined by a measure of the greater capacity of such a permanent crew over that of the annually recruited outfit. The advantage of holding, in idle times, a shrewd superintendent, expert machine operators and capable foremen is reflected in their ability to work more effectively in busy times, and the overhead cost of keeping them may be further offset by using them to put all equipment in first class condition. Also, the restriction which equipment places on capacity indicates that you need to devote more attention to this care, upkeep and frequent overhauling of machinery. With special reference to the operation of equipment, it is to your advantage that you secure the highest type operators or train them and pay what is necessary to retain them. The time lost and the neglect and careless handling of machinery by a poor operator pay for an expert. All of these considerations suggest the necessity for rigid control of and thorough and specific knowledge of unit costs of performing work and for constant study, under your several conditions, of the exact productive ability of each of your outfits.

Our studies have covered practically every sort of highway construction such as grading and grading equipment, paving of the more common types, and some structural work, including concrete and steel bridges. We have accumulated sufficient data to obtain average performance for many of the above items. A relatively small amount of these data has as yet been published but we expect to publish before very long a bulletin on grading work which should be of considerable interest.

It is not my intention to discuss any of the contractor's work items in great detail. The subject is one which would require for that purpose a very lengthy paper. I will, rather, call attention to what I conceive as some of the high spots in a line of work with which no doubt all of you have more or less contact—highway grading.

Effect of Hauling on Profits.—Most grading work involves hauling the material a greater or lesser distance. But the cost of hauling varies not only with the distance but also with the condition of the road over which the hauling is done. Studies on well over a hundred grading jobs show that here is one place where most grading contractors part with a part of their possible profits. We have many examples where for lack of the effective work of a small maintenance crew in keeping the hauling road in shape, the road speed of the hauling units was so reduced and the wear and tear on the equipment so accelerated as to practically double the cost of the hauling.

On a certain job six 5-yd. trucks were working with a shovel handling about 600 cu. yd. per day. The haul distance averaged 1,479 ft. and the speed of the trucks was fixed by time studies at 439 ft. per minute. Two $4 per day men were put to work smoothing the road. A few days later the trucks were averaging over 900 ft. per minute and four trucks were doing the work of six. The cost of hauling dropped from 1.42 cts. to 1.06 cts. per station yard. Based on 8,874 station cubic yards per day, the saving amounted to $31.94 per day for an expenditure of $8.

Practically all road grading work consists of the consecutive repetition of a limited number of rather simple operations. But in order to secure and maintain a high rate of production it is necessary, first, that delays or interruptions to production be reduced to the lowest possible limit consistent with economical operation; second, that no secondary operation be permitted to delay or interfere with any primary operation; third, that each operation be performed with the most economical expenditure of time and energy and, fourth, that each operation be so performed as to yield the largest possible useful contribution toward the completion of the work in hand.

Saving Seconds Makes Profits.—There is an old adage to the effect that if you take care of the pennies the dollars will take care of themselves. Adapt this to road construction and it may well be worded, Take care of the seconds and you will seldom need to worry about the profits. Many of the operations involved in almost any kind of highway construction work involve only a few seconds. Practically all of these operations are repeated over and over again, sometimes several thousand times a day. Consequently, any time loss or time extension on each of such operations is multiplied by the number of times the operation is repeated.

The daily cost of operating almost any road grading outfit is very nearly fixed for any given set of conditions, regardless of whether the output is

Turning a Heavy Truck on Soft Ground Is Slow Work. On Short Hauls It Usually Pays to Back the Loaded Truck to the Dump and So Do Away with All Turning

high or low. The only effective means available to the contractor for reducing his unit costs is therefore to increase the rate of production. The attention of the contractor must therefore, in general, be directed toward finding ways and means for attaining and maintaining the rates of operation and loading fixed by the primary unit of his equipment.

Fresno Operation.—Thus, for example, the rate of fresno operation is almost entirely a matter of proper plowing and general management so long as the material is such that it can be so broken up or loosened that it will load readily. The direct effect of the material in fresno work is therefore largely expressed in the amount of stock and number of men that must be used in order to get it properly plowed. But the amount of such material which is carried to the dump per fresno load varies over a somewhat wider range with the nature and character of the material, as well as with the care of the drivers. The contractor must therefore not only watch the rate at which his outfit is moving, but he must also see that the loading is kept up to the highest possible point.

In fresno work the various necessary operations of loading, dumping, turning at each end of the trip and throwing the fresno back into loading position can readily be performed within an average time of 40 seconds. To maintain this rate might be termed good or excellent management. For all jobs studied to date the average time for these operations is somewhat over one minute. Where the management is poor or very lax, the time required for these operations often approaches two minutes per trip, which on short haul work means a 50 per cent decrease in production.

Under normal conditions a good fresno team will ordinarily walk at an average round-trip speed of from 220 to 240 ft. per minute. As the time per trip is the sum of the times required to perform the several operations of loading, dumping and turning, plus the actual travel time to and from the dump, including any delays or waits which may occur, anyone can readily determine how the work on a particular job compares with the best or average rate at which many other jobs have been found to be working.

Variation in Fresno Production.—The rate at which a round-trip should be made for various lengths of haul and the production possible at each rate under the three proposed grades of management are as follows:

Variation of Fresno Production When Operating Under Good, Average and Poor Management in Average Common Excavation

Haul (Ft.)	Time required per round trip—Min.			Cubic yards per hour possible at this rate		
	Good	Aver.	Poor	Good	Aver.	Poor
50	1.1	1.6	2.4	18.2	12.5	8.3
75	1.3	1.8	2.6	15.4	11.1	7.1
100	1.5	2.0	2.8	13.3	10.0	7.1
150	2.0	2.5	3.3	10.0	8.0	6.1
200	2.4	2.9	3.7	8.3	6.9	5.4
250	2.9	3.4	4.2	6.9	5.9	4.8
300	3.3	3.8	4.6	6.1	5.1	4.3
400	4.1	4.6	5.4	4.9	4.3	3.7

Wheel-Scraper Operation.—The same general conditions which govern fresno work have also been found to hold good in regard to the use of the wheel-scrapers. The only essential difference is that wheelers require the use of a snatch team in order to secure sufficient power for loading and this, therefore, places a more definite limit on the number of wheelers which can be advantageously employed for any given haul in each gang. Hooking on and unhooking the snatch team also increases the loading time so that the time-constant, that is, the total time required to perform the standard operations of loading, dumping, turning, etc., is considerably longer for the wheeler than for the fresno. There is also more of a tendency for waits and delays to occur at the cut, especially where the management is not constantly alert. On the other hand, there is a tendency for the teams to maintain a slightly faster pace and to tire less than on the longer fresno hauls. With good or excellent management on wheeler work the time-constant can be kept within an average of two minutes per round-trip, while the average for all jobs which have been studied is very close to three minutes. In general, the fresno is more economical than the wheeler for hauls up to 300 or 400 ft. Consequently, the number of studies which have been made on very short haul wheeler work is somewhat limited.

Variation in Wheeler Production.—For hauls of 200 ft. and over, however, the average time required per round-trip and production possible at each rate are about as follows:

Variation of Wheeler Production When Operating Under Good, Average and Poor Management in Average Common Excavation

Haul (Ft.)	Time required per round trip—Min.			Cubic yards per hour possible at this rate		
	Good	Aver.	Poor	Good	Aver.	Poor
200	3.7	4.7	5.6	8.1	6.4	5.4
300	4.5	5.5	6.5	6.7	5.5	4.6
400	5.3	6.3	7.3	5.7	4.8	4.1
500	6.2	7.2	8.2	4.9	4.2	3.7
600	7.0	8.0	9.0	4.3	3.8	3.4
700	7.8	8.8	9.8	3.9	3.4	3.1
800	8.7	9.7	10.7	3.5	3.1	2.8

Spreader Boxes and Finishing Machines Save Much Hard Labor in Asphalt Work

The elevating grader and the power shovel are excavating and loading machines which, except where casting can be done, depend on wagons, trucks or tractors for hauling the excavated material to the point where it is to be placed. With the fresno and wheeler the operations of loading, hauling and placing the material are all performed by the same piece of equipment in consecutive order. With the elevating grader and the power shovel, however, we have in general the work divided into three definite parts. The grader or shovel does the digging and loading only. Other equipment must be provided for hauling the material and, in general, still further equipment or facilities to handle the material after it has been dropped on the dump by the hauling equipment.

Elevating Grader and Power Shovel Work.—Both the elevating grader and the power shovel are capable of a very high rate of production but require far more careful management in order to maintain such a rate consistently and efficiently. The reason for this is clear: In fresno work, for example, the supervision in addition to ordinary oversight need only see that the plow teams are sufficient, that the plowing is well done and that the number of fresnos in each group is not spaced so closely, as to cause interference or delays. In general, the plowing can be done well ahead of the fresno requirements. If the capacity of the plow team is much greater than that of the available fresno teams, it can frequently be alternated between fresno work and plowing. But neither the elevating grader nor the power shovel can so store up their work. In general, they can dig only when and as hauling equipment is in position to receive the material. Up to the point of their maximum rate for the material in which they are working, the hauling equipment therefore controls the rate of production providing the dump is properly managed, for it is clear that the hauling equipment can handle the material no faster than it can be received at the dump.

Coordination and Synchronization of Equipment.—In order to maintain a high rate of production at the most economical cost with either the elevating grader or the power shovel, it is therefore necessary that both the amount of equipment and its operation be carefully coordinated and synchonized with the output capacity and operating speed of grader or shovel. For example, more hauling equipment than is required is just as much of a waste, though seldom as expensive, as is not enough. This is equally true of equipment unsuitable either in size or operating characteristics to work well with the major equipment. Thus, with a power shovel it has been found impossible to operate a hauling equipment so as to maintain a high rate of production on long hauls if the capacity of the individual hauling unit is only one dipperful. Also, in yielding soils or those which do not pack readily it is almost impossible to maintain a low production cost with heavy trucks and especially so if the hauls are short.

Hauling Equipment.—No two jobs are just alike and hauling equipment suitable for one may not be suitable for the other.

To maintain the proper amount of hauling equipment is a question which should be given much attention by the management. The amount of equipment needed at any particular time depends on the length of the haul and this is constantly changing from cut to cut and sometimes from hour to hour. If too much is supplied, some will be idle or all will be operating at a low rate. If not enough is supplied the shovel or grader will lose time by waiting for wagons or trucks. Hiring additional equipment for the longer hauls is sometimes possible, or where two graders or shovels are operated the work can often be so planned that when one is on short haul work the other will be on the longer hauls and the hauling equipment shifted accordingly. If none of these expedients seems practical, an analysis should be made of the entire job so as to determine the most economical number of hauling units for the job as a whole. Such an analysis is always well worth while, for most power shovel jobs are more of a problem in hauling than in digging and loading.

Fields of Elevating Grader and Power Shovel.—But, while many of the operating characteristics of the elevating grader and the power shovel are similar, each has a rather distinct field. The elevating grader is not adapted to rocky, very sandy or stumpy ground, nor to ground where the side slopes are steep or the longitudinal surface slopes are abrupt and much broken. The ideal field of the elevating grader is level to rolling prairie regions, where cuts are usually fairly long and the side slopes slight so as to avoid much dead-heading and the soil reasonably free from rocks, large boulders or many stumps and roots. So long as these conditions hold, it does not matter much whether that cut is only a few or many plowings in depth.

Be Sure That You Know What the Specifications Mean Before You Bid. One Contractor Bid on Rip-Rap Expecting to Do Work Like That Pictured at the Left But Found What He Had Contracted to Do Was Really of the Kind Shown in the Illustration at the Right

On the other hand, the power shovel is far less affected by the contour of the surface or the character of the material. Very shallow cuts, however, slow down production to a rather surprising extent. But neither the power shovel nor the elevating grader can, in general, do shallow short haul work in common excavation as cheaply as the fresno.

Points in Elevating Grader Work.—In elevating grader work a high rate of production is dependent very largely on the following points: (1) Keeping the plow cutting at the bite which will give the elevator the maximum amount of material that it can handle without clogging or undue strain, especially on the high side of the cut, (2) A sufficient supply of suitable hauling equipment, (3) Operating the grader at the proper speed, and (4) Proper operation of the hauling equipment, especially as to exchanging wagons. Long cuts of fairly uniform depth with but little side slope will, of course, yield much higher average daily production than short cuts with steep side slopes and of variable depth.

Where team-drawn wagons are used for hauling the grader speed should be maintained at about 3¾ ft. per second or 225 ft. per minute. If 1½ cu. yd. wagons are used the teams can readily be made to walk at the rate of 4 ft. per second, so that if the loading is begun at the front end of the wagon the gain of the team over the grader will be just sufficient to complete the load without spilling. The empty wagon should be made to follow hard on the wagon completing its load. The loaded wagon should immediately swing away sharply from the grader and then continue forward until clear of any chance of interfering with the following wagon. This method will facilitate a quick exchange of wagons and reduce grader delays.

Time Requirements for Elevating Grader Work.—The following time requirements for each of the principal operations will tend to illustrate the effect the management in elevating grader operation:

Elevating Grader Work

Time Required for the Various Operations

	Grade of Management Good or Excellent	Aver.	Poor
Loading time, seconds	18	23	30
Exchange time, seconds	7	13	20
*Turning time, seconds	35	45	55

With motorized hauling equipment the grader can usually be speeded up to 250 ft. per minute or even more providing the soil is entirely free from stones, stumps or heavy roots. The rate of loading should therefore be increased and since the capacity of these units is usually greater than the capacity of the ordinary horse-drawn dump wagon, the actual standing time of the grader should be decreased. But otherwise, we find the same general rules of operation which apply when horse-drawn vehicles are used also hold good when motorized hauling equipment is substituted with the elevating grader.

*Time required to turn grader at end of cut.

One of the most important improvements to the elevating grader is a power take-off from the tractor to operate the elevator. This considerably extends its usefulness, enabling its use in sandy material and in muddy ground where it is difficult to get proper traction from the bull wheel. Experiments are also being made with an independent power unit for the elevator.

Power Shovel Operation. — Under favorable conditions in good common excavation, a power shovel can be made to load wagons or trucks at the rate of four well filled dippers per minute, providing the swing does not exceed 90°. A very good operator can continue this rate for intermittent periods throughout the day. This, however, is very close to the maximum limit of shovel operation and permits of no delay or interference of any kind. However, many jobs have been found where under normal field conditions in materials which were easy to dig and dump the rate of operation was at the rate of three well-filled dippers per minute. But to maintain this rate consistently requires a shovel in first-class condition, a high-grade operator, an ample supply of suitable hauling equipment, loading at the side of the shovel so that the average angle of swing does not exceed 90° and, above all, a carefully trained and well supervised personnel. A continuing rate of three well filled dipper loads per minute in good common excavation may therefore be taken as the measure of excellence in the management of a power shovel job. As the materials become hard, tough or sticky, the digging becomes more difficult with the result generally that both the number of dipper loads per hour and the yardage per dipper-load are reduced. No very satisfactory way has yet been found for designating the rate at which this decrease varies with the kind or character of the materials and the grade of the job management. The following table, however, represents a somewhat tentative average for varying degrees of management and kinds of material as found from a study of nearly a hundred different highway grading jobs on which power shovels were used.

Importance of High Grade Management and First Class Equipment.—These examples and averages selected from many hundred studies illustrate rather clearly the effect of management on the rate of production. Yet many contractors somehow still seem to feel that they cannot afford the cost of high-grade management and first-class equipment. But the cold hard facts are that you pay directly and indirectly for the equivalent of both high-grade management and first-class equipment, whether you have them or not. Here is an illustration:

During a study of a grading project in Missouri it was found that the lack of personal supervision by the contractor, or in lieu of him a capable superintendent, together with his oversight in placing some worn out equipment on the job, caused a loss of 187 hours out of a possible 300 hours that he might have been producing and increased his cost per yard from 15.1 cts. to 26.9 cts. Operating at 37.4 per cents efficiency, his time was divided as follows:

	Per Cent
Production at limited capacity	37.6
Loss due to rain and wet grade	26.8
Mechanical trouble breakdowns, etc	18.7
Hauling equipment supply and operation loss	11.1
Operation and miscellaneous delay	6.1
Moving shovel	4.7
Total time	100.0

This contractor over a period of seven months actually lost a total of $10,870 which was far more than enough to have provided him with expert supervision, the needed new equipment and excellent operation. This contractor thus actually paid in

Variation of Power Shovel Production When Operating Under Good, Average and Poor Management in Various Materials

Kind of Material and Condition	Dippers per hour of Continuous operation (average angle not to exceed 90°) Good	Aver.	Poor	Cubic yards per hour based on quantities measured in place in cut or borrow pit Good	Aver.	Poor
1. Common excavation which digs easily and dumps clean and freely	180	150	120	90	75	60
2. Common excavation which dumps freely and is so hard or tough that full bite exceeds available power at normal engine speed	150	120	90	70	55	40
3. Common excavation which digs easily but which sticks or hangs somewhat in dipper	160	130	100	75	60	45
4. Common excavation, hard or tough and which also generally hangs or sticks somewhat in dipper	120	90	60	50	40	25
5. Well blasted material containing few or no pieces too large to load and dump freely	140	110	80	55	40	30
6. Very hard or tough and adhesive material, poorly blasted shale or rock, hard or sticky soils with many boulders or roots and stumps and all materials consistently difficult to both dig and dump	100	75	50	35	25	15

The above outline is based on a ¾ cu. yd. shovel with crawler tread, in first-class condition, a good operator and supplied with sufficient hauling equipment so as to not cause any retardation from this cause except as normally occurs due to the various grades of management. Quantities all based on measurement of materials in place as obtained from cross-sections of cut or borrow pit. Shovel assumed to work in cut averaging 4 feet deep or more.

lost profits for these things but did not receive any of them.

Finally, in closing, I wish to express my appreciation of the cooperation the bureau has had from the contractors on all the jobs of which we have made studies. Without such cooperation we could have made but little progress. I not only bespeak your further cooperation, but also your criticism of our work. It is our desire to make the work of value to all who are concerned in highway improvement, and your views will be of inestimable help to us.

Acknowledgment.—The foregoing is a paper presented before the Missouri Branch of the Associated General Contractors.

Waterproofing Concrete with Asphalt Planks

The problems of making concrete impervious to water are numerous and varying. The Universal Asphalt Plank Company of Chicago, Ill., announces the development of asphalt planks for this purpose.

Asphalt saturated fabric properly and permanently bonded to a concrete surface, proves a most satisfactory protection to the concrete. The concrete surface should first be primed with an asphaltic primer, and the fabric laid on a hot mopping of waterproofing asphalt. The fabric should be applied in one, two or three layers with broken joints. The failures in the use of fabrics are many. Where the water gets in back of the fabric it may be easily lifted from the concrete surface and its value as a protection will become nil.

On many projects, such as track elevation, where this method is usually employed, the failures are not due so much to the waterproofing as they are to the nature and type of protection which is placed over the waterproofing.

Universal asphalt planks composed of 65 per cent by weight of asphaltic saturated felt have been recognized as a protection to waterproofing on track elevation work. They are resilient at all temperatures because of 25 per cent by weight of felt which they contain. They are claimed to add 65 per cent of waterproofing value in the protection course.

These asphalt planks are also used for wearing surfaces on bridge floors and where combinations of wearing surfaces and waterproofing are desired. They are furnished in any thickness from ½ in. up and in sizes from 12 in. by 36 in. to 30 in. by 60 in.

It is particularly impervious to water, is unaffected by acids, is tough and resilient within itself and can be bonded to concrete surfaces. Where the concrete is dry an asphaltic primer coat should be applied followed as necessity may dictate with two or more primer coats. This to be followed with a mopping of hot Karnak W. P. asphalt or its equivalent. Universal asphalt plank is laid into the asphalt while still hot.

Where there is to be considerable wear or where there is apt to be movements of the structure, two or three layers of asphalt planks should be used, bonding each one with the previous application of hot asphalt and taking pains to seal all joints. Any normal movements of the concrete will not affect the asphalt plank protection.

The asphalt planks can be made in any cross section and therefore can extend up and over copings and into raggle blocks. Special sections of sphalt plank are furnished for cant strips, flashing, etc., to prevent possible leakage.

The asphalt planks are so tough and durable that they are even being applied over thin concrete as a wearing surface on bridge floors. They can be made to fit the needs of each problem.

Crossing Elimination from Federal Highways

A total of 390 railroad grade crossings were eliminated from the Federal Aid Highway System in 1928, according to the U. S. Bureau of Public Roads.

Of the 390 crossings eliminated in 1928, 107 were grade separations and 283 were excluded by relocation of highways.

According to figures of the bureau, covering the period 1917 to Dec. 31, 1928, a total of 4,291 crossings have been eliminated on the Federal Aid System with Federal aid—947 through grade separations, and 3,344 through relocation of highways.

For the year 1928, Wisconsin heads the list of eliminations, with a total of 35. Alabama is second with 31; Michigan, third with 26; Texas, fourth with 25; Indiana, fifth with 24; Kansas, sixth with 23; and Montana, seventh with 22. Georgia and Illinois each are credited with 21, and Mississippi with 17.

For the period from 1917 through 1928, Texas heads the list with a total of 440 eliminations. Minnesota is second with 321; Iowa, third with 212; Wisconsin, fourth with 204; North Dakota, fifth with 193; Georgia, sixth with 182; Oklahoma, seventh with 162; Illinois, eighth with 161; Kansas, ninth with 153, and North Carolina, tenth with 132.

Status of Railroad Grade Crossing Elimination on Federal Aid Highways

State	Railroad grade crossings eliminated from Federal Aid System during 1928 with Federal aid			Railroad grade crossings eliminated from Federal Aid System from 1917 to December 31, 1928, with Federal Aid		
	No. of crossings excluded by grade separation	No. of crossings excluded by relocation of highway	Total No. of crossings eliminated	No. of crossings excluded by grade separation	No. of crossings excluded by relocation of highway	Total No. of crossings eliminated
Alabama	12	19	31	38	91	129
Arizona	2	0	2	6	19	25
Arkansas	0	3	3	11	65	76
California	2	3	5	18	20	38
Colorado	3	4	7	13	33	46
Connecticut	0	2	2	5	2	7
Delaware	0	0	0	0	0	0
Florida	0	0	0	7	25	32
Georgia	6	15	21	40	142	182
Hawaii	0	0	0	0	6	6
Idaho	2	3	5	13	44	57
Illinois	3	18	21	40	121	161
Indiana	1	23	24	18	91	109
Iowa	0	0	0	59	153	212
Kansas	3	20	23	27	126	153
Kentucky	0	4	4	19	76	95
Louisiana	0	1	1	7	14	21
Maine	1	2	3	1	18	19
Maryland	1	0	1	9	5	14
Massachusetts	0	3	3	0	9	9
Michigan	4	22	26	22	45	67
Minnesota	4	4	8	76	245	321
Mississippi	3	14	17	25	60	85
Missouri	5	2	7	45	65	110
Montana	5	17	22	13	75	88
Nebraska	0	3	3	11	118	129
Nevada	1	2	3	10	42	52
New Hampshire	0	0	0	1	10	11
New Jersey	2	2	4	7	17	24
New Mexico	2	8	10	7	28	35
New York	1	2	3	26	34	60
North Carolina	0	3	3	19	113	132
North Dakota	2	6	8	16	177	193
Ohio	5	9	14	16	57	73
Oklahoma	6	5	11	51	111	162
Oregon	2	0	2	11	40	51
Pennsylvania	4	2	6	31	84	115
Rhode Island	1	0	1	4	0	4
South Carolina	3	3	6	26	94	120
South Dakota	3	2	5	19	77	96
Tennessee	1	0	1	26	55	81
Texas	5	20	25	88	352	440
Utah	0	0	0	6	30	36
Vermont	0	0	0	1	10	11
Virginia	0	3	3	8	58	66
Washington	0	6	6	4	60	64
West Virginia	0	4	4	6	22	28
Wisconsin	12	23	35	35	169	204
Wyoming	0	1	1	6	36	42
Totals	107	283	390	947	3,344	4,291

Recent Changes of Design and Specifications

How They Affect the Highway Contractor

By GEO. N. CHILDS
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THE design of a structure, and the specifications covering its construction are the two things governing, to a large extent, the cost of the completed project. The ideal plan and specification is one which gives the maximum of strength, utility, and beauty at a minimum cost and is, of course, the end to which all engineers strive. Any changes, therefore, in existing designs or specifications should be made with this idea in mind.

The Difference Between Theory and Practicability.—Contractors are often inclined to resent changes as they usually result in the abandonment of still useful equipment, or the training of their forces in new ways. This resentment is natural for too frequently he finds that the engineer, in making the change, has failed to differentiate between theory and practicability. In pavements, particularly concrete pavements, changes both in design and specification are inevitable, for irrespective of the fact that some engineers, and many contractors, conceitedly think they know all there is to be known about concrete, nevertheless, it is, relatively speaking, a new type of pavement, which signifies room for improvement. This does not mean, however, that designs should be changed, or specifications rewritten merely to the end that they be altered, as has been the case in some instances.

Constructive criticism should not offend. I submit for consideration, the propositon that there have been far too many instances where changes have been made that failed miserably, by reason of their impracticability, which could have, and should have been foreseen by those making them. Changes are the cause of much expense to contractors, and in the end to the public, so should be made only after careful study and experiment, so that little, if any, doubt remains that the contemplated change is a worth-while improvement.

In the way of testing by practical experiments before making changes, I feel the Illinois Highway Department is entitled to much credit—more than they have ever received, for out of their tests in the so-called "Bates Road," a design for concrete pavement slab has been developed that is a complete reversal of all former designs. These changes have since been adopted by nearly every state in the Union, and as a result millions of dollars have been saved to the country. Although the effect of these changes to methods and equipment of contractors was far reaching, I have never heard one of them complain, because they realize that changes resulting from such extensive tests will be permanent and for the good of all concerned.

When the "Sun Shades" Went Bad.—Some highway departments design in detail particular devices to be used, or plans to be followed by the contractor. I believe this is a mistake, and one which may result in serious consequences for there is little question that the engineer in so doing guarantees the sufficiency of his design to the exclusion of all others. I recall an instance of this kind that will illustrate what I have in mind. A few years ago, the highway department of one of our states designed a so-called "Sun Shade," that was to be furnished by all contractors working in the state, in a quantity sufficient to cover at least one-half day's run of slab. The construction of the shade to be used was completely covered by the design, and consisted of slats bowed and fastened together which were to be covered with muslin or duck of a certain grade so that when completed it resembled a huge raised umbrella, wide enough to extend across the width of the pavement and about 12 ft. long. In spite of the protests of the contractors, the department insisted on the use of the device, and each paving outfit equipped itself with a suffiicent number of these shades to cover 400 or 500 ft. of road. It is not hard to visualize what happened. After each wind storm the crews of the contractor were busy recovering the "Sun Shades" from the tree tops and from the roofs of buildings instead of paving. The result was that the department cancelled their order and the contractor tried to forget the hundreds of dollars invested in the "Sun Shades." Would it not have been much better for this department to have stated in their specifications that the newly laid slab should be protected from the sun rays and left the means of the protection to the contractor?

Specifications Should Be Clear.—Perhaps the greatest criticism to be made of the average specification is that it lacks clearness and is indefinite. This is a matter of vital interest to a contractor as he makes his livng solely by carrying out its provisions. Specifications should possess such clearness of statement and such fredom from ambiguity as is humanly possible, for they become a part of the contract. It is a fundamental legal conception of a contract, that there shall be a meeting of the minds of the contracting parties. If such meeting of the minds is not achieved when the contract is signed, trouble is most sure to follow, in which the contractor is usually the chief sufferer.

Most specifications will devote paragraphs, if not pages, in a minute description of how the work is to be done; what materials are to be used and all other details, and end contrarily by saying, "If not satisfactory to the engineer it may be changed by him, his decision being final." I recall the statement of my attorney after examining the first paving contract we entered into. Throwing the contract on his desk, he said that anyone signing it wanted to do business d—— bad, for in so doing he did what equalled putting his head into a lion's mouth. In a way he was right, for the authority given the engineer in the average paving contract exceeds the authority of the Kaiser in his most balmy days.

I am happy to state, however, that it is my belief and my experience that in general, the engineering profession accepts its judicial responsibility to the contractor in a most creditable manner, although there have been a few infrequent cases where I have felt that the impartial standards of a supreme court justice have not been quite attained. The contractors pay high compliment to the engineer in signing without hesitation the average construction contract. The fact that so few lawsuits result from these contracts speaks well for the personnel of not only the engineering but the contracting fraternity as well. So I repeat, specifications should be clear, comprehensive and specific, for every time an uncertainty is removed the cost and price of work is lowered.

Some Drastic Changes.—Having expressed my views on the importance of the engineer being specific, it is fitting that I discuss recent changes in design and specifications more specifically. I wonder if we are aware of how drastic some of these changes are. It is but a few years ago that we were laying pavements on a flat sub-grade; the slab was thicker in the center than at the edge, and the reinforcement, if any, was placed transversely. Contrast this with the modern design, with its parabolic crowned subgrade, edges 50 per cent or more thicker than center and with center strip and reinforcement placed longitudinally.

More recently we find some states requiring the measurement of aggregates by weight. This change, I believe, will soon be adopted by all highway departments as its soundness is well established, and contractors considering the purchase of new equipment, may well anticipate this requirement. In instances where the contractor supplies the cement and where proportions of aggregate are definitely established by ratio of fine to coarse the saving in cement almost compels the use of weighing devices. Other methods of measurement are in use that are somewhat a departure from the older mode of measurement by volume, one being the inundation, but on account of its the inundation, I believe the weight measurement will be the one eventually adopted.

The water content of concrete is receiving much attention by engineers. Tests in process at present, and others, recently completed, promise to reveal some rather startling information on the difference in strength of concrete secured by variation of the volume of water used. Recent experiments seem to point out that proportions of aggregate are of less importance than has been heretofore believed and that the water content is in reality the determining factor. Present practices will without doubt be improved, and changes with respect to amount of water used and the time it is introduced into the mix are certain for unquestionably the resultant strength is largely determined by it. This is an instance, however, where extensive tests should be made before radical changes are decided upon. If the mix is to be stiffened to a slump required in some cases, it will involve new designs in mixing, tamping and finishing equipment, as machines in use at present will not handle it successfully.

Quality Concrete in Wisconsin.—The State of Wisconsin has approached this in a new and rather unique manner, namely, by specifying a certain strength of concrete to be attained within a stated period of time, leaving the kind of aggregate, the proportions, and the water content to the discretion of the contractor. Should he fail to produce a concrete of the desired strength he is penalized up to a certain point, beyond which his work is rejected. Several of these so-called "Quality Concrete" contracts were built during the past season and as far as I am able to learn were very satisfactory to the state and to the contractor as well. There seems to be much in this plan to recommend it although the trials are too few and recent to be considered other than in the nature of an experiment. The success of the scheme will involve the engineer specifying results only. Any attempt to dictate the manner or method to be used by the contractor, requiring him at the same time to guarantee results, would be manifestly unfair.

Curing Concrete Pavements.—The opening of pavements to travel is receiving the attention of many engineers and presents a difficult problem. The economic loss during the curing period of concrete pavements compels attention, and in a measure will determine the value of this type of surfacing material. Unless the curing time of concrete can be substantially reduced, other materials will eventually supersede it. In metropolitan areas there are many instances where this is already a reality. To meet this situation, we find engineers specifying mixtures aimed to attain sufficient strength to permit travel within a much shorter period of time than heretofore. Admixtures of calcium chloride, hydrated lime and other materials are being experimented with to expedite the set. To accomplish this requires a change in the mixing time, and will result in the use of larger paving mixers by contractors specializing in city work.

The curing of concrete has a direct bearing on the length of time required before travel can safely be permitted. There has been a wide difference of opinion of engineers on this subject in the past. Recently, however, the value of calcium chloride and silicate of soda, as curing agents, has become generally approved. The use of bituminous materials has been adopted in some states and the results give promise of being very satisfactory. The cost of these materials is somewhat in excess of the old method of using earth, but the time gained and the reduced crew more than compensate for the loss.

Opening Pavement to Traffic.—It seems to me that present practices of arbitrarily holding to a certain number of days before pavement is opened to traffic is wrong and should be changed without undue delay. Certainly concrete pavement laid in August is ready for travel in less length of time than that poured in early spring or late fall months; also, climatic conditions in various locations must cause a variation in length of time required for the curing period. Why then should an arbitrary number of days be specified that shall elapse before the pavement is open to traffic, and fail completely to take cognizance of temperature, soil conditions or curing methods? Such a clause in any specification is indefensible, and must eventually be changed. Does it not seem reasonable to believe that some method to determine the actual strength of the concrete should be used, and that a practical device be designed, which will furnish the desired information? The states which require the casting of beams at the time and of the same material and under the identical conditions existing when the slab is being poured, have, I believe, made a big step in approaching this problem from the proper direction. From these beams the actual strength of the concrete is determined by flexural tests that establish exactly what the modulus of rupture is, making it possible to open pavements on the day the slab has attained a desired strength. Effects from these changes, when made, will be most advantageous to contractors, permitting them in many instances to travel the new pavement much sooner, thereby accomplishing a saving in hauling costs, and other savings, which are self-evident.

Bidding on Time of Completion.—Another change receivng serious consideration by some highway departments is worthy of mention here. The plan contemplates taking the time recost of detouring is a part of the consideration in determining the low bidder. Briefly, the contractor is to state in his proposal the number of days he will require to complete the contract. A predetermined value per day is arrived at by the officials, usually by multiplying the miles of detour by the vehicles per day times the estimated cost per mile, it being assumed that cost of detouring is a part of the contract price. The contractor bids on time as well as cost of doing the work, both units being considered when awarding the contract. Should the time consumed in doing the work exceed that named in the proposal tendered, an amount equal to such excess days times the value per day is deducted from the contract price. Likewise, in the event a shorter period of time is used to complete the contract, a sum, arrived at in like manner, is added. In congested areas and on heavily traveled roads, this plan promises to be of great value and should be given fair trial. As yet it is merely hypothetical.

Prequalification of Bidders.—Prequalification of bidders is fast becoming a reality, and is welcomed by all experienced contractors, as through its use, when properly pursued, benefits to the industry are sure to accrue. These advantages are enjoyed by the public as well, for seldom, if ever, does anyone profit from the low bid of an inexperienced or unresponsible contractor. In public work it is next to impossible to eliminate this type of bidder in any other way, and therefore this change should be welcomed by all public officials. The preparation of qualified lists of bidders entails much grief for those preparing them as irrespective of how honestly or carefully they are made, bitter criticism will surely follow. Political influence will manifest itself unless rigidly barred. Many crafts, whose activities bring them less in contact with the public, are required to be licensed. It seems reasonable then to expect that progress in the direction of qualifying contractors will soon be made by those states, that as yet have not done so.

In conclusion, it can be truthfully said that on the whole the changes, which have been made, both in designs and in the specifications, have been of such a nature that the art of paving

and the quality of the product have been greatly advanced, and reflect much credit to those responsible for them. These changes as they affect the contractor have been of a beneficial nature, for, in the end his interests are mutual with those of the engineers and the public.

While there still remains much room for additional improvements, and it is inevitable that in the adoption of these changes, some will be found impractical, nevertheless, with the continued interest and efforts of those, who have so faithfully devoted themselves to this problem in the past, I believe we can rest secure in the thought that the welfare of the contractor and of the public will be safeguarded.

Acknowledgment.—The foregoing paper was presented at the 1929 convention of the American Road Builders' Association.

New Alaska Aerial Survey Expedition

An expedition known as the Alaskan Aerial Survey Detachment, representing cooperation between the Navy, Agriculture, and Interior Departments, is now outfitting and will soon proceed to Alaska for a continuation of the task of making air pictures as a basis for maps of certain areas of that territory. It is in charge of Lieut. Commander A. W. Radford. Other members of the party are Lieut. E. F. Burkett, executive officer; Lieut. Commander A. C. Smith, medical officer; Lieut. Thomas Macklin, in charge of the airplane tender; and Lieuts. R. F. Whitehead, C. F. Greber, L. P. Pawlikowski and E. F. Carr.

R. H. Sargent, topographic engineer of the Geological Survey, who will accompany the expedition as official representative of the Interior and Agriculture Departments and act in an advisory capacity, will join the expedition at Seattle and fly to Alaska in one of the planes.

The expedition consists of the airplane tender Gannet, a 140-ft. barge equipped for quartering the photographic and aerial units, and four Loening amphibian planes of the latest type.

The decision as to the places at which the expedition will base during the summer will be made by the commanding officer after he arrives in Alaska.

During the summer of 1926 an expedition was sent to Alaska by the Navy Department, at the request of the Interior Department, to make aerial photographs of the islands of southeastern Alaska, to obtain material for the compilation of maps of areas whose topography is so rugged as to make mapping by ground methods particularly difficult. An area of approximately 10,000 square miles was photographed by this expedition, which yielded over 5,000 photographs for use in mapping, in addition to many photographs of areas of special economic interest.

Some of the photographs made in the course of this work have already been used by the Geological Survey in compiling a map of a portion of the area, and the photographs are proving extremely useful to the Forest Service in studying the distribution and extent of the forests and the amount of timber and in determining the available water power in southeastern Alaska. It is estimated that the development of the pulp-manufacturing industry in southeastern Alaska has been advanced several years by the information obtained on this expedition.

Three large islands in this part of Alaska—Kuiu, Chichagof, and Baranof—and many thousands of square miles of the mainland have not yet been photographed. Both the Geological Survey and the Forest Service desire to obtain photographs of these areas, and the Navy Department has therefore been requested by the Departments of the Interior and Agriculture to continue this work during the coming summer.

Road Program of Manitoba, Canada

Details of the road construction and surfacing work planned for the province of Manitoba during 1929 have been announced by the Public Works Department. Capital estimates for the trunk highway program call for the expenditure of $3,600,000 during the year. This involves the construction of some 365 miles of new highways and the resurfacing of 502 miles, practically all resurfacing work to be gravel. There is an additional allowance made of $885,000 for maintenance work. The outstanding feature of the highway program calls for the expenditure of $200,000 on construction of a road running eastward to the Ontario boundary. This will be a most important connecting unit in the Trans-Canada highway when it is completed and great expectations are held for a tremendous increase in tourist traffic. The total cost to Manitoba will approximate $500,000. It will connect at a point on the Manitoba-Ontario boundary, almost directly west of Kenora, with a road which the Ontario government has promised to build from Fort William to the boundary, via Kenora. This road will probably be completed in time for use in the summer of 1931.

Tax on Alcoholic Beverages in Favor of Road Building in Latvia.—According to regulations published in the "Valdibas Vestnesis" No. 70 of March 26, 1929, the law regarding the imposition of a 3 per cent tax on all alcoholic beverages in favor of road building in Latvia is effective on and after April 1, 1929. The 3 per cent tax is assessed on the basis of the average retail price which shall be determined by the Tax Department.

Ohio's New Policy in Calls for Bids

Director Robert N. Waid of the Ohio State Department of Highways has announced his policy as to the manner of inviting bids for construction work. Heretofore alternate types of construction were advertised for letting on practically all projects. This involved much engineering effort on the part of the department of highways and to the contractors likewise. Hereafter Director Waid will advertise for one specific type of construction, where the material and type of construction has been agreed upon by the state and county authorities. Where no specific type has been agreed upon, and where there is reasonable question of doubt as to what type should be selected, or where it is likely that competition in types will result in a saving in cost, bids on alternate types will be taken as formerly. This plan seems to meet the hearty approval of all concerned. Contractors will not be compelled to estimate material and labor costs on a number of types of construction where only one is to be considered. Engineers of the state department will be saved from preparing plans and estimates which will not be used. All other interested parties will profit accordingly.

Analysis of Highway Maintenance Expenditures

The following table from the 6th (1927-28) biennial report of the Division of Highways of the Department of Public Works of California shows the distribution of the maintenance dollar on state highways in 1927:

Class of Work	Amount of each dollar spent, Cents
Where spent—	
Traveled way	54.5
Roadside	30.7
Improved shoulders	3.0
Structures	6.4
Safety devices	2.0
Drifts	.6
Trees	1.2
Miscellaneous	1.6
Total	$1.00
Class of Expenditures	
Labor	44.2
Equipment costs	32.8
Materials	20.6
Service and expense	2.4
Total	$1.00

State of Sao Paulo, Brazil Highway Program for 1929.—Appropriations for highway purposes in Sao Paulo for 1929 provide for the completion of 197.5 miles of new roads before January, 1930; 98.1 miles of new roads were completed during 1928. In December, 1928, there were in Sao Paulo State 1,684 miles of state highways. In addition, there are about 6,213.6 miles of municipal roads, the Brazilian "municipality" being the equivalent of the "county" in the United States.

Acquiring the Research Habit

By HALBERT P. GILLETTE

KNOWLEDGE consists in knowing facts; wisdom, in knowing their relationships. Perhaps this is a rather arbitrary distinction between these two words, but it serves at least to emphasize the difference between mere fact gathering and the discovering of the significance of facts.

"Those who refuse to go beyond a fact rarely get as far as fact," said Huxley, and he added, "anyone who has studied the history of science knows that almost every great step therein has been made by the anticipation of nature, that is, by the invention of hypotheses which, though verifiable, often had very little foundation to start with."

In a letter written in 1861 Charles Darwin said: "About 30 years ago there was much talk that geologists ought only to observe and not theorize; and I well remember someone saying that at this rate a man might as well go into a gravel pit and count the pebbles and describe the colors. How odd it is that anyone should not see that all observation must be for or against some view if it is to be of any service." At another time he said "I am a firm believer that without speculation there is no good and original observation."

Coming from a man who was one of the most painstaking of observers and experimenters, and the author of a theory that is without equal in its effect upon biological science, such an attitude toward the framing of scientific hypotheses is not to be brushed aside. Darwin's biographers all say that he was exceptionally prolific in devising hypotheses to explain phenomena. One of them quotes him as saying: "Hence it has become a passion with me to try to connect all such facts by some sort of hypothesis." And again: "I have steadily endeavored to keep my mind free so as to give up any hypothesis, however much beloved (and I cannot resist forming one on every subject), as soon as the facts are shown to oppose it." However, he did not live up literally to this last statement, for several times when his theory of evolution seemed to be seriously controverted by certain facts, he clung to it. Many a competent naturalist, such as Agassiz, cited many a fact that seemed to be unanswerable by Darwin's theory, yet Darwin adhered to his belief in its fundamental soundness. Apparently he reasoned that a new theory should be judged mainly by what it explains rather than by what it fails to explain.

The doctrine that was prevalent a century ago among geologists and astronomers, to which Darwin made reference in the letter above quoted, still controls not a few scientists. Recently an experienced astronomer wrote the editor that the time is not yet ripe for theorizing about the origin of our solar system. If Darwin is right, the time was ripe for such theorizing when Galileo made his telescope. Commenting directly upon such matters. Darwin said: "How many astronomers have labored their whole lives on observations, and have not drawn a single conclusion."

In a letter written in 1871 he says: "I have been speculating last night what makes a man a discoverer of undiscovered things, and a most perplexing problem it is. Many men who are very clever—much cleverer than the discoverers—never originate anything. As far as I can conjecture, the art consists in habitually searching for the causes and meaning of everything which occurs."

There is a world of truth in this last statement, but the word "habitually" should have been printed in capitals. How to become an habitual seeker of causes and meanings is a great problem. Darwin not only denies that his training in two universities failed to make him such a seeker, but he asserts that his university time was mostly wasted: "During the three years which I spent at Cambridge my time was wasted, as far as the academical studies were concerned, as completely as at Edinburgh and at school." He was born in 1809, and when he was at Cambridge physical science was little taught. Yet it is rather surprising to hear so modest a man say: "I consider that all I have learnt of any value has been self-taught." Surely he did not have in mind what he learned from books, but regarded that as part of his self-taught knowledge. The opening chapter of his "Origin of Species" contains many references to books and articles by men who had had more than mere glimpses into the secrets of evolution, and his biographers tell of his painstaking indexing and abstracting of books and articles throughout his long and industrious life. We are, all of us, prone to regard what we learn in that manner as being "self-taught." Henry Ford, in his book, makes the same error, for he speaks of his careful reading of all that could assist him in designing automobiles, and then adds that he learned most from his own experiments. That he learned most from published matter is beyond question when consideration is given to what he himself added to the art of automobile designing.

When we see what Darwin accomplished without much aid from his university training, and what Ford accomplished with no such aid, and remember that many another originator and inventor has succeeded greatly in spite of little scientific schooling, it should be evident that most of science can be learned from books and articles, without the assistance of teachers. Moreover, it is almost self-evident that any studious man of middle age has necessarily learned vastly more from the printed page after his formal schooling ended than he learned at school.

Darwin's rebellious attitude toward Cambridge may have come from his perception that Cambridge did nothing to make him an habitual inquirer as to the causes of things. If so, then most of our American graduates of colleges and universities could justify a similar rebellion. We have yet a long road to travel in America before it is generally realized that the primary function of schooling is to make the students habitual inquirers. Only in a few American institutions of higher learning is training conducted continuously so as to effect that result. Studying the fundamental principles of science does not accomplish that result. Mathematical training does not. Then what does? Nothing but repeated practice in systematic searching for the answers to questions, and particularly to questions that can be answered only by the collecting and weighing of many facts.

If it be objected that we can not all be Darwins or Fords, and that such men will always find ways of training themselves, then the objector has completely failed to understand the primary object of mental training. It is not to acquire knowledge, or even to acquire wisdom, that we take courses of study in college, for neither is acquirable to any considerable extent during the schooling period. It is to become habituated to secure and analyze facts with a view to answering some definite question.

The question may be, What is the most economic pavement to lay for the service that it will probably be required to render? Simple though it sounds, this is a very difficult problem in many cases. The question may be, What business or profession should I enter and where? More than 99 per cent of men guess at the answer, for they have never been habituated to solve problems by the fact-gathering method. The question may be, Why is my business unprofitable although my competitor is thriving? No solution is there for such a problem other than fact-gathering and analysis. Nearly all the problems in life are of these sorts, and then solution is correctly made only by those who are either instinctively fact-hounds, or have become habituated to searching for usable facts and their significance.

Sub-Soil Studies and the Highway Engineer

An Interesting Discussion of the Phenomena of Soil Movement

By V. R. BURTON
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SUB-SOIL studies of various kinds have recently engaged the attention of very many highway engineers. Much of the work done, while fundamental in its line and interesting in its ramifications, is yet of little practical value to the engineer. We must have conclusions drawn in a definite way showing the effect of the soil properties on the design of works of engineering before they can ever become usable. A mathematical analysis of some few, a very few, problems giving a rational design may be possible. Others are incapable of any such solution, and must, from a practical standpoint, forever remain an empirical problem offering only statistical solution.

Problems with which engineering research workers in soils should concern themselves nearly always involve soil movement. I say nearly always, because there is the problem of the effect of alkaline soils on concrete, for instance, which is purely a chemical one not connected with any physical cause. In general, however, most problems for whose solution laboratory sub-soil studies are made, primarily involve soil physics and physical chemistry to the exclusion of the purely chemical.

Colloidal Content Important Factor.—The most important physico-chemical factor which determines in a basic way the character of any sort of soil material, is its colloidal content. The answer to the question, what is a colloid, is not so easy, as a good many different theories are in vogue, but the generally accepted idea is that it is a group or clot of molecules of certain non-crystalline substances too large to pass through a parchment filter. Its effect on the soil material may be easily understood when it is known that in sands it varies from nothing up to 8 or 10 per cent, in clays the amounts may run up to from 50 to 75 per cent commonly, and in some peats is practically 100 per cent. As the colloidal content of the soil increases, its suitability as a subgrade decreases. This colloidal material is the soil cement holding the finer particles of silt and sand together and we must recognize its presence in any thorough-going laboratory soil study. Critics of this statement have completely misunderstood the colloidal function and its importance. It has been said that the study of the colloidal content is comparable to a study of the chemical composition of cement used in concrete. Nothing is farther from the truth. The colloidal content is the cement and while we are not particularly interested in whether or not it is an aluminum or ferric compound, we do not want to know how much of it there is in the soil material and the strength of its affinity for water.

A great deal of work has been done by soil scientists in the study of colloids with reference to its effect on the agricultural problem. Until very recently little attention was paid by engineers to the enormous mass of literature available on the subject, accumulated by soil scientists primarily interested in agriculture. It is felt that so far as soil materials are concerned, a thoroughgoing study of the colloid fraction is imperative if we are to obtain any fundamental understanding of their peculiar behavior under various conditions. Some idea of its importance may be obtained when it is realized that the following soil phenomena are directly dependent on the amount and character of the colloidal material: Attraction for water, adhesion, amount of water which will freeze in the soil, vapor pressure, evaporation, water holding capacity, capillary movement, percolation, plasticity, soil structure and shrinkage.

Must Deal With Soil Movement.—Turning from the realms of physical chemistry to the purely physical, we are primarily and fundamentally interested in those phenomena of soil movement with which we must deal. We have first and most important of all plastic flow, concerning which, unfortunately, very little is known. A plastic material is defined as a solid which holds its shape permanently under the action of small shearing stresses, but readily deformed under a somewhat larger stress. On the application of shear a certain part of the force applied is used up in overcoming the internal friction of the material and when the stress overcomes this friction plastic flow is produced.

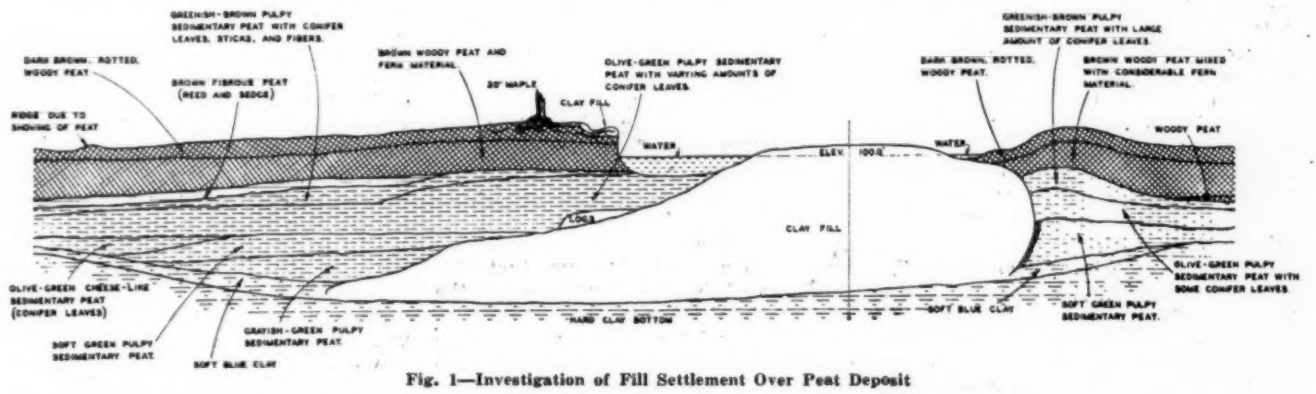
GREENISH-BROWN PULPY SEDIMENTARY PEAT WITH CONIFER LEAVES, STICKS, AND FIBERS.
DARK BROWN, ROTTED, WOODY PEAT
BROWN FIBROUS PEAT (REED AND SEDGE)
RIDGE DUE TO SHOVING OF PEAT
BROWN WOODY PEAT AND FERN MATERIAL
20" MAPLE
CLAY FILL
OLIVE-GREEN PULPY SEDIMENTARY PEAT WITH VARYING AMOUNTS OF CONIFER LEAVES.
WATER
ELEV. 100.0'
LOG
CLAY FILL
OLIVE-GREEN CHEESE-LIKE SEDIMENTARY PEAT (CONIFER LEAVES)
SOFT GREEN PULPY SEDIMENTARY PEAT
GRAYISH-GREEN PULPY SEDIMENTARY PEAT.
SOFT BLUE CLAY
HARD CLAY BOTTOM
GREENISH-BROWN PULPY SEDIMENTARY PEAT WITH LARGE AMOUNT OF CONIFER LEAVES.
DARK BROWN, ROTTED, WOODY PEAT.
BROWN WOODY PEAT MIXED WITH CONSIDERABLE FERN MATERIAL.
WATER
WOODY PEAT
OLIVE-GREEN PULPY SEDIMENTARY PEAT WITH SOME CONIFER LEAVES
SOFT BLUE CLAY
SOFT GREEN PULPY SEDIMENTARY PEAT.

Fig. 1—Investigation of Fill Settlement Over Peat Deposit

Plastic flow when produced by pressure of a small area on a very much larger body of plastic material has received scant attention from investigators. This condition produces both a shear at the edges of the area and a compression beneath it. Some studies have been made of the flow of plastic materials in a confined space from the standpoint of the imperfectly elastic effects of compression and from the standpoint of the flow under pure shear. But, so far as is known, very little has been done on a study of the manner in which a pressure is dissipated in a plastic material beneath a small bearing area, with the plastic material free to move from beneath this area.

It is this phenomenon which interests us in the study of safe bearing values for foundations for structure. How much settlement of the foundation may we expect and to what distance will the earth pressure caused by the load be communicated before being dissipated in the surrounding earth? When

may we be assured that further settlement will not be of a material amount?

The Michigan Tests.—Some work has been done along this line by various investigators. One of the most interesting of these tests was carried on jointly by the Wayne County Road Commission and the Civil Engineering Department of the University of Michigan. This test was inaugurated for the purpose of determining safe bearing values for foundation for the Fort St. viaduct in Detroit and is reported by W. J. Housel in the September, 1928, issue of "The Michigan Engineer." Loads on both square and round bearing plates in sizes of 1, 2, 4 and 9 sq. ft., were applied and the rate of settlement and extent of the communication of lateral pressure and shape of the displaced soil next the plate studied.

It was found that the larger part of the settlement of the plates under load was due to the plastic flow of the material nearest the plate and a smaller amount to compression. It is the concept of Mr. Housel that a pressure bulb is formed beneath and beyond the bearing area, temporary in character, which lasts only until the compression of the material within it has increased the internal friction to such an extent that equilibrium is established and flow ceases. The soil has been readjusted to its new condition by further consolidation and any active pressure disappears.

According to this article, where the cohesive strength was low and the fluidity high the shearing strength on the perimeter of the shearing plate was very small and the pressure bulb appeared at once. "The fluid characteristics of this soil make it relatively incompressible. If this material could be effectively confined, its bearing capacity would be greatly increased, but the very low cohesive strength does not furnish enough confining influence to make it suitable for carrying foundation loads. Consolidation of the material within the regions if inequality of pressure takes place very slowly, if at all. Foundations in this type of soil may never get beyond the temporary stage of the pressure bulb, but will be slowly settling over a long period of years. Bearing capacity in this type of soil is limited by the allowable rate of settlement, and the possibility of establishing equilibrium through the low cohesive power of the soil aided by the static head of the surrounding body of earth."

Fill Settlement in Peat Marshes.—I have quoted at length from this article as the discussion of these phenomena of plastic flow is distinctly applicable to the problem of fill settlement in peat marshes. This problem is of particular interest to those of us whose work lies in glaciated territory. Most of us in laying out roads have always avoided locations across open water in lakes, and yet we have many times run a line across a peat marsh with an innocent looking surface which proved to be almost as bad as open water would have been. In some instances, the results have been even worse, because of the fact that settlement occurred later on, necessitating frequent and expensive repairs.

This situation is caused by the flow of the peat from beneath the fill material in much the same way as has been described in the foundation tests. There is a definite load which the peat will carry and when this load is exceeded flow starts. As was noted in the bearing area tests both by Goldbeck, in work done for the Bureau of Public Roads, and by Housel in the Wayne County work, total load plays a very big part. In many instances, where a narrow fill has satisfactorily carried the traffic for years without appreciable settlement, widening will cause flow to start and very serious settlement occurs. This is the case even where the grade was not raised to any extent and where comparatively large amounts of earth were placed in the original roadbed.

There is a difference, however, which alters the conclusion that materials lacking any very great cohesive force, and of high fluidity, will not consolidate. Time is a large element in this consolidation and if the material subjected to pressure remains for a considerable time under this pressure before relief may be obtained by a vertical expansion, there will be considerable consolidation. This means that the thickness of the peat layer beneath the fill largely determines the amount of settlement which will take place before equilibrium is established, both by consolidation of the peat and by the static head of peat heaved up at the side. Therefore in filling peat marshes there is no particular cause for alarm when heaving begins. In fact in deep deposits there should be much more concern shown if, after considerable fill material is placed, no heaving appears.

Investigations of Fills on Peat Marshes in Michigan.—A great deal of work has been done in the investigation of fills on peat marshes in Michigan. This problem causes us considerable trouble, as the peat deposits are very widespread in our state and many times we must cross them in spite of the knowledge that we might almost nearly as well cross open water of the same depth. Somewhere about 3 per cent of our paved mileage is on this material.

In 1925 we made a fairly complete examination of a large number of fills over these deposits with depths ranging from 1 to 66 ft. It became evident almost at once that the depth of the peat was by far the most important factor in determining the depth to which the fill would penetrate the peat. The character of the peat material did not seem to have such a marked effect, although there was a considerable difference observed between the effects of fill over peat and over lake clays. The slope of the mineral sub-soil beneath the marsh deposit was also found to affect quite markedly the amount of fill material necessary in these places since there was always a tendency for the fill material to flow down hill. A diagram was prepared from the data given by the large number of cross sections examined and an average curve gives the penetration to be expected for each depth of peat. A separate curve was necessary in order to determine the effect of lake clay. This purely empirical analysis indicated that the fill settlement increased uniformly in rather small amounts up to about a depth of 20 ft. As the depth exceeded 20 ft. the penetration increased very rapidly until at 26.5 ft. the peat was practically all displaced and the fill material reached the bottom instead of practically floating on it as in the shallower depths.

The shape of the cross section of the fill in this earlier investigation was nearly uniformly within vertical lines drawn from the toe of slope at the marsh surface down to the bottom of the deposit. In most cases the bottom of the earth mass was less than the top in width by approximately the amount of the horizontal projection of the side slopes from the shoulder to the marsh surface. In 1927, and the early part of 1928, it was discovered that we were in some cases underestimating very greatly the amount of fill material necessary for certain deep peat deposits. It was quite evident from the amounts of overrun reported that there must be some swelling out beyond the vertical below the marsh surface.

A special study was then made of the deeper deposits and 60 more cross sections were taken in eleven different marshes. It was quite a blow to our preconceived notions of how these fills should act, to discover that in a number of instances there had been a considerable amount of lateral displacement taking place far beyond the vertical line below the toe of slope. The older locations which were the basis of the former study were again examined and in two instances it was found that the cross sections taken had just missed the points at which some swelling had occurred.

How the Fill Acts.—Two cross sections showing this phenomenon are given in Figs. 1 and 2. Figure 1 shows the fill made by dumping from a trestle with the material hauled with industrial railway equipment. The fill material is a fairly heavy clay becoming plastic with higher moisture contents. As will be seen, displacement took place laterally for a distance of about 130 ft. on one side, following the slope of the hard clay bottom. This was the fill which showed the most displacement of any one of those examined and it will be noted in the cross section that the depth of sedimentary peat both of a pulpy and cheeselike character, is very great. This sort of material flows very readily, on account of its highly col-

loidal content. Compaction of this material is very difficult and little resistance to the plastic flow of the fill material, much of which was dumped directly into water, is afforded.

Fig. 2 shows quite a different phenomenon of plastic flow of the fill material in that the material spreads out along the bottom for a long distance without any serious flow at the higher levels. Here again, we see very great depths of the highly colloidal types of peat, and, as in the former case, the fill was made from a testle with industrial railway equipment.

Fig. 3 shows a fill made with sandy material where the depth is very much greater than either of the other two

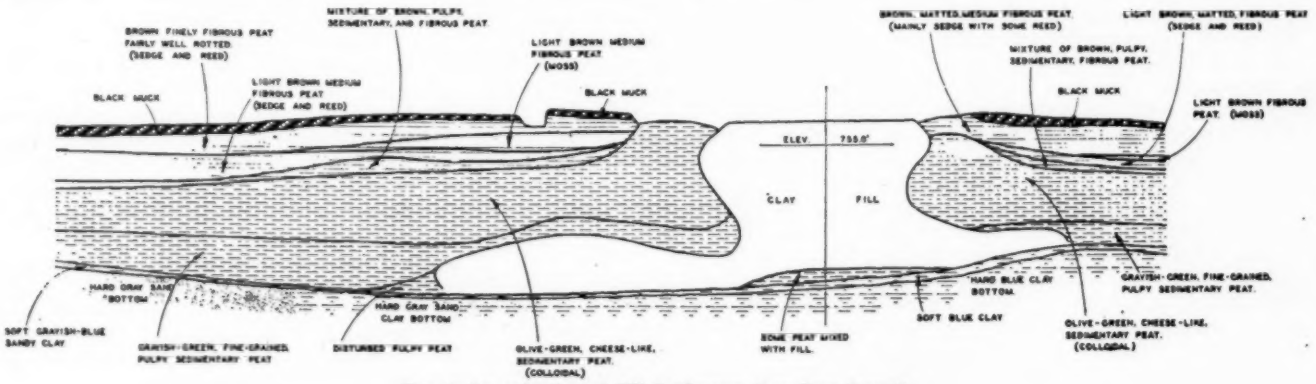
BROWN FINELY FIBROUS PEAT FAIRLY WELL MATTED (SEDGE AND REED)
BLACK MUCK
LIGHT BROWN MEDIUM FIBROUS PEAT (SEDGE AND REED)
MIXTURE OF BROWN, PULPY, SEDIMENTARY, AND FIBROUS PEAT
LIGHT BROWN MEDIUM FIBROUS PEAT (MOSS)
BLACK MUCK
ELEV. 755.0'
CLAY
FILL
BROWN, MATTED MEDIUM FIBROUS PEAT (MAINLY SEDGE WITH SOME REED)
MIXTURE OF BROWN, PULPY, SEDIMENTARY, FIBROUS PEAT.
BLACK MUCK
LIGHT BROWN, MATTED, FIBROUS PEAT (SEDGE AND REED)
LIGHT BROWN FIBROUS PEAT (MOSS)
HARD GRAY SAND BOTTOM
SOFT GRAYISH-BLUE SANDY CLAY
GRAYISH-GREEN, FINE-GRAINED, PULPY SEDIMENTARY PEAT
HARD GRAY SAND CLAY BOTTOM
DISTURBED PULPY PEAT
OLIVE-GREEN, CHEESE-LIKE, SEDIMENTARY PEAT, (COLLOIDAL)
EDGE PEAT MIXED WITH FILL
HARD BLUE CLAY BOTTOM
SOFT BLUE CLAY
GRAYISH-GREEN, FINE-GRAINED, PULPY SEDIMENTARY PEAT.
OLIVE-GREEN, CHEESE-LIKE, SEDIMENTARY PEAT, (COLLOIDAL)

Fig. 2—Investigation of Fill Settlement Over Peat Deposit

cross sections shown. The fill material here, however, was a very coarse sand, and in spite of the fact that the depth of sedimentary peat is very great, only a small amount of lateral displacement has taken place. This fill was made with trucks from a runway established on the old corduroy road in existence when the fill was started. It appears probable that the use of non-plastic material in this fill was very greatly reduced the tendency to lateral flow, and, in addition to this, the use of trucks over the material in the later stages of construction tended to compact the material going in. If the material had been of a plastic nature it is probable that the compaction afforded by this method of placing would have materially reduced plastic flow. In 10 out of 12 cases where lateral flow occurred, the fills had been constructed with industrial railway equipment, with no means of compacting the fill as it was placed. The use of teams or trucks insures a considerable amount of compaction while the fill is being deposited and from present indications it appears that wherever possible this method should be used during construction.

It has been our policy in filling over peat marshes to insure as complete settlement as is possible during construction so as to minimize the amount which is liable to occur later. In the case of the deeper deposits no special methods are necessary in obtaining complete penetration, except destroying the top crust by ditching or blasting before the fill is placed. The most difficult depths to handle are those from about 7 or 8 to 20 ft. These deposits are not deep enough to insure complete penetration by loading alone and too deep for us to follow our common practice of excavating and removing from the roadbed peat up to 7 or 8 ft. in depth. When the depth becomes deeper than this the plastic peat flows into the trench to such an amount that this method is impractical.

Aiding Compacting With Dynamite.—It has been found, however, that the use of dynamite along the edge of the fill after it has been heavily loaded, will, in many cases, insure considerable further settlement and aid in compacting the material which may be left beneath the fill.

At the present time we are putting down holes 10 feet apart, along the shoulder line, by means of the driving of scrap water pipe fitted with a wooden plug at the lower end. This pipe is driven to a point about half way between the bottom of the fill material to the bottom of the marsh. The wooden plug is then driven from the pipe and a half stick of dynamite exploded in order to create a pocket in which the rest of the dynamite may be placed. From 20 to 30 sticks of 50 per cent straight nitro-glycerin dynamite are placed in this pocket and from 100 to 150 ft. of road shot at the same time. This is very effective in forcing the fill down and compacts the peat to a remarkable degree.

The method of filling is different in the intermediate depts as well, as two separate fills are used at first and every effort made to drive these wedges of earth down as far as possible, both by an excess of loading and by the method of blasting just described. After these fills are driven as deep as possible, the center is loaded with the excess dirt and left to settle. This excess is later spread out to form the finished road bed. There is some question as to the advisability of this method without some revision. In one or two instances some settlement has occurred in the center, and in another case the pressure of the center loading was sufficient to force the two wedges apart. It is therefore difficult to decide on just how far this loading may go in order to sufficiently compact the peat and still not increase the yardage by driving the two wedges apart. Further investigation along this line is necessary in order to determine whether or not this method should be abandoned.

Plastic Flow and Landslides.—A further manifestation of the effect of plastic flow on highways is shown in the landslide so common in southeastern Ohio, southwestern Pennsylvania and northwestern West Virginia. A thorough-going study of this subject has been made by George E. Ladd, associate Economic Geologist, of the U. S. B. P. R., and is reported in the April, 1927, and October, 1928, issues of "Public Roads."

According to Mr. Ladd, landslides exhibiting the phenomenon of plastic flow are the predominant type in the area studied. The material composing the slide is usually a mixture of shale and sandstone detritus which varies in clay content from small to rather large amounts. Even in cases where the clay lubricant was nearly absent and the fine particles were largely composed of sand and silt, their form was highly rounded. This shape of the particles accompanied by a high water content creates a quicksand condition which permits of a movement quite as free as that material in which there is a higher percentage of clay.

Masses of this material on the hillsides become unstable when the moisture content exceeds a certain critical point which varies with the character of the mass. The increased water content not only increases the lubricating properties of the materials, but adds weight to the mass, and when the internal friction is overcome by the shear forces arising from gravity the whole mass slides down hill. Not only does this movement affect material outside of the construction lines of the highway, but cut banks and side fills composed of this material are also subject to it. The remedy is, of course, the maintenance of a water content below the critical amount wherever drainage can be effected.

Effects similar to these landslides

have been observed in the use of materials for heavy fills which become plastic in the situation in which they are placed. This is especially true of very fine sands and extremely fine grained or, one could well say, highly collodial clays. Some of these materials when placed on a 1½ to 1 slope begin to flow, the slope bulges and when sufficient of a bulge has occurred a slough of the material follows. This action steepens the slope above the slough and more flow and sloughing follows. The only remedy for this situation is to place the material on a slope flat enough to stand, or, if large quantities of it must be used with some small amounts of better material available, place it in the interior of the fill and cover the sideslopes with a heavy blanket of the material which will take a steeper slope.

Plastic Flow Beneath Traffic.—Some plastic flow also takes place beneath road metals, especially where the moisture content has been greatly increased during freezing and subsequent thawing. The material flows out from beneath the edge of the slab under heavy loads, leaving it unsupported and breakage then occurs. The thickened edge undoubtedly helps some to confine this plastic material, but much better results are secured in using a width adequate to keep heavy loads away from the edge, thus eliminating or reducing the flow. This explains one of the reasons why we are successful in decreasing our thickness of pavement below that which good rural design calls for, in cities where we use wider pavements with curb and gutter.

The flow of soil material beneath traffic loading is by far the most important subject connected with pavement failure, and yet it has been scarcely recognized. We say that a clay soil when the "frost is coming out of the ground" has practically no bearing value. Water contents are observed which are far above anything which may be produced by saturating the unfrozen material. This clay and water mixture becomes practically a clay suspension, and as such is, when confined, almost incompressible. What, then, may we learn from studies on the compressibility of a soil in this state? The cohesive power is practically zero and the fluidity enormously high and for this and moisture contents much below it we need fundamental knowledge of the laws of plastic flow where the material beneath the load is free to move.

Besides plastic flow, there are other soil movements of great importance effecting highway work. The direct forces resulting from the expansion of frozen material is productive of much damage to both rigid and non-rigid surfaces. Pavement is heaved and broken, macadam is pushed up in a mound in which all bond is broken, gravel is humped up and the traffic bound crust destroyed. When thawing occurs, the broken surfaces go back into place over a material which is about the consistency of a good, thick pea soup. Flow of the material at once takes place and serious damage results.

It was pointed out in an article on the "Causes and Cure of Frost Boils," by G. C. Dillman, in the 1927 Proceedings of the National Research Council, that direct expansion from the freezing of soil was not sufficient to account for frost heaves. There must be an addition of water to the affected place while the soil is still frozen, in order to produce vertical movements in the amounts observed. This addition, it was said, may occur in a number of ways; first, from the water contained in the soil itself, with additions from the unfrozen material below, by the freezing of ice in the capillaries; second, it may come from an actual water flow under hydrostatic head through porous soil near the frost heave; third, it may come from the thawing of ice underneath the pavement and flow to the affected place by gravity. It is possible that a fourth might be added in the transfer of water vapor from the warm region of high pressure below the frost line to the colder low pressure surface.

While the foregoing reasons serve to explain the existence of frost heaves, only those which are predicated on a transfer of moisture directly through the frozen soil can serve to explain the supersaturation following these heaves in a heavy soil. This is quite evident when it is considered that in many clay soils percolation of the water downward is practically an impossibility, especially in a clay already filled with water to normal saturation. There would then be no chance for the water formed on the thawing of layers of ice between pavement and soil to add anything to the water content below, unless the soil were already practically a liquid suspension.

Further evidence along this line is had from an unpublished study "Investigation of Slab and Subgrade Under Low Temperature" made in Illinois during the winter of 1923-1924. Mr. Clemmer observed that "the moisture content (of the soil) will also follow the temperature cycle very closely, being much greater during freezing periods than during the warmer months, irregardless of the amount of rainfall and coming back to normal after the frost leaves the ground in the spring of the year."

Investigation of Moisture Transfer Through Frozen Soil.—This phenomenon of moisture transfer through a frozen soil is to be investigated by the Michigan State Highway Department, in co-operation with the University of Michigan, at Ann Arbor. A cold room capable of carrying a sustained temperature of more than 20° F. has been built in which to do the work. Soil cylinders 36 in. long extracted from actual frost heaves will be placed in this room and a definite frost line maintained within the soil. These cylinders will be kept frozen for long periods and the moisture contents near the surface determined from time to time. In one cylinder capillarity will be free to act, in another it will be broken so that it will be possible to determine whether or not the action is largely a transfer by capillarity by water vapor rising through the soil. This question is highly practical as the results secured from it will, to a large extent, determine the proper sub base material to be used to correct the situation arising from frost heaves.

Other soil movements are of importance to highway engineers, although they are by no means so productive of difficulty as those which have already been discussed. These other effects are largely erosive. The first is the effect of frost on masses of rock overhanging the highway, or on slopes so steep that when the forces of frost break loose the rock, particles are precipitated on the highway. This causes considerable trouble in mountainous territory, but is not a phenomenon which is of a great deal of interest to us in the Mississippi Valley.

Sand Movement.—Another erosive effect, which, however, is of a great deal of importance is the movement of sand under the action of wind in the dune area. These sand dunes, when denuded of vegetation, begin to move under the influence of the wind with a movement which is practically irresistable, trees and buildings are buried beneath the advancing mound of sand and there seems to be little which we can do to stop it. In some cases snow fence has been used so as to pile up the sand near the crest of the dune. This sort of a process cannot be continued indefinitely on account of the fact that when the height of the drift formed is sufficient to bury the fence another fence must be placed on top of it and finally the slope of the sand material becomes so great that any further raising of the crest height by means of the fence simply means that the sand will slide down hill, rather than blow over over the crest. The only real remedy for stopping the advance of sand dunes lies in the restoration of some sort of vegetation which will hold it in place.

The erosive effect of running water is also a soil movement which is productive of some trouble to highway engineers. Certain classes of soil, light in texture, are very easily affected by running water and serious washouts may occur after heavy rains. There is one routine soil test which gives a very good indication of the behavior to be expected of the soil from the results of the test. This test is known as the slaking test and simply consists in measuring the time taken by compressed disk of the soil in slaking away in a water bath. It is the only one of our so-called routine soil tests which, to my knowledge, has any direct bearing on the highway engineer's problems.

All of the phenomena spoken of so far in connection with soil movements are capable of a common sense solution without any highly technical laboratory soil studies. Fundamental knowledge of the laws of plastic flow is desirable, but by no means indispensable in attacking the problem. When it comes to the question of the effect of soils which are more or less intermediate in character, on pavement condition, it is thought by some that the laboratory study affords a practical means of attack. I am extremely doubtful as to whether or not anything but a statistical solution of this problem is possible.

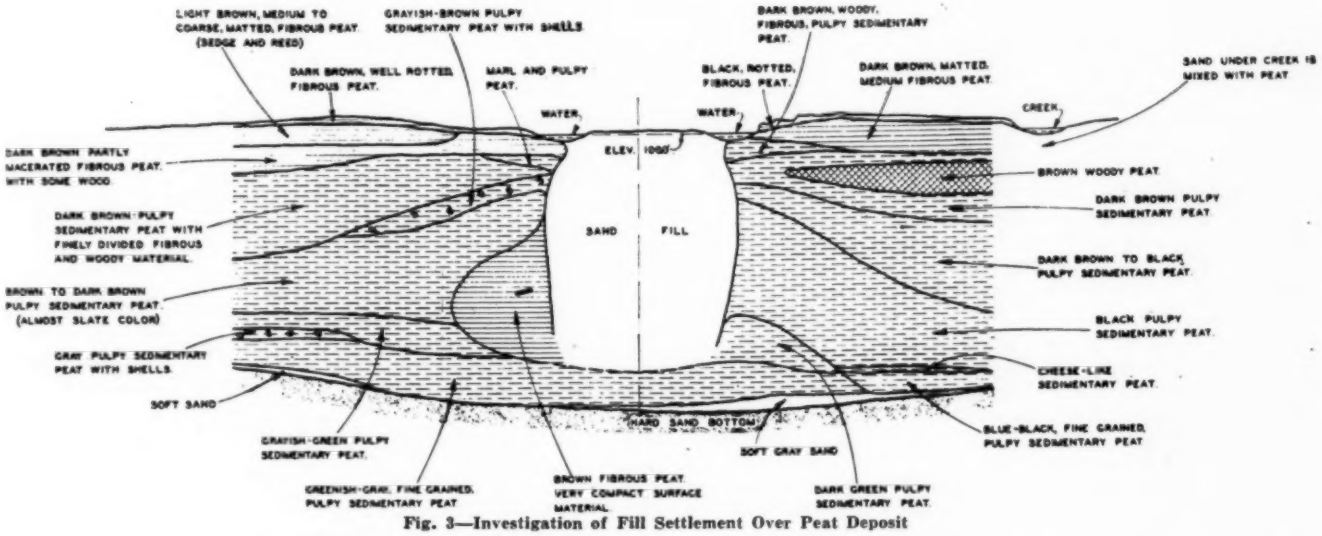
LIGHT BROWN, MEDIUM TO COARSE, MATTED, FIBROUS PEAT. (SEDGE AND REED)
GRAYISH-BROWN PULPY SEDIMENTARY PEAT WITH SHELLS
DARK BROWN, WOODY, FIBROUS, PULPY SEDIMENTARY PEAT.
DARK BROWN, WELL ROTTED, FIBROUS PEAT.
MARL AND PULPY PEAT.
BLACK, ROTTED, FIBROUS PEAT.
DARK BROWN, MATTED, MEDIUM FIBROUS PEAT.
SAND UNDER CREEK IS MIXED WITH PEAT
WATER.
WATER.
CREEK
ELEV. 1000'
DARK BROWN PARTLY MACERATED FIBROUS PEAT, WITH SOME WOOD
BROWN WOODY PEAT.
DARK BROWN PULPY SEDIMENTARY PEAT WITH FINELY DIVIDED FIBROUS AND WOODY MATERIAL.
SAND
FILL
DARK BROWN PULPY SEDIMENTARY PEAT.
DARK BROWN TO BLACK, PULPY SEDIMENTARY PEAT.
BROWN TO DARK BROWN PULPY SEDIMENTARY PEAT. (ALMOST SLATE COLOR)
BLACK PULPY SEDIMENTARY PEAT.
GRAY PULPY SEDIMENTARY PEAT WITH SHELLS.
CHEESE-LIKE SEDIMENTARY PEAT.
SOFT SAND
HARD SAND BOTTOM
BLUE-BLACK, FINE GRAINED, PULPY SEDIMENTARY PEAT
SOFT GRAY SAND
GRAYISH-GREEN PULPY SEDIMENTARY PEAT.
GREENISH-GRAY, FINE GRAINED, PULPY SEDIMENTARY PEAT
BROWN FIBROUS PEAT, VERY COMPACT SURFACE MATERIAL.
DARK GREEN PULPY SEDIMENTARY PEAT.

Fig. 3—Investigation of Fill Settlement Over Peat Deposit

Soil a Vertical Profile of Different Classes of Material.—Many engineers have the idea that a soil is a simple material when, as a matter of fact, it is a vertical profile of different classes of material which, for purposes of classification and identification, are known by the manner in which the varying layers are arranged. These layers differ from each other in color, texture, structure and composition, both physical and chemical. Variation in the characteristics of the various soils is noted by type names. The nomenclature used is universal throughout the United States and is kept uniform through the agency of the U. S. Bureau of Soils, to whom all new types are referred for correlation. Profiles of mature soils in our climate consist of an upper layer of extraction called the "A" horizon, from which clay and silt has been removed by mechanical transfer, leaving it lighter in texture, and second, a layer of concentration called the "B" horizon, which is heavier in texture, because of the silt and clay concentration caused by the removal of this material from the "A" layer. The parent soil beneath the "B" horizon is called the "C" horizon and is the original geological material which, in most of the northern United States, consists of glacial drifts and settlements. For engineering purposes it has been found necessary to add a "D" layer in cases in which the parent soil is directly underlain by a different type of geological material.

The Wausau Silt Loam.—A brief description of the Wausau silt loam found in Michigan will give an idea as to the variations in texture to be found in a single soil profile. The top 8 to 12 in. consist of a dark brown soil containing a high percentage of humus, below this is from 4 to 6 in. of a brown silt loam whose coloring is derived from the humus, below this horizon is a compact, tight clay from yellowish brown to reddish in color, varying in depth from 7 to 18 in., underneath this is a gravelly open substratum extending for considerable depth below.

The practical impossibility of determining the effect of this soil on pavement, from a laboratory study of the physical properties of samples from this soil, is perfectly apparent. In order to have an adequate idea of the physical properties of these soils, at least four samples would have to be investigated. If we wish to know the relative effects of the physical properties of these soil horizons on each other, and on pavement which may be laid on any part of this variable profile in going from cut to fill, or in cuts of varying depth, it can easily be seen that the mathematics of soil mechanics might become somewhat complicated.

The only way in which we may hope for a knowledge of effects of the different types of soil on pavement structures is by careful correlation of the soil type with the design of pavement in a statistical way. In this statistical study it will be necessary to take into account all of the factors which may to any considerable degree influence the condition as it exists at the time of the investigation. Obviously the design of the pavement cross section, the underdrainage of the subgrade, the depth at which the pavement is laid in the soil profile, the age of the pavement, the grade on which it is laid, the height of the water table,—in the case of some sands, the strength of the pavement as shown by the mix used, the presence or absence of steel reinforcement, and many other factors must be taken into account in a study of this kind. In order to be able to study the effect of a single variable, all of the other factors must be the same when the effect of this variable is studied. Soil types vary within comparatively short distances, as do, of course, grade, underdrainage, etc. Work of this kind involves a slab by slab comparison, rather than the study of a considerable stretch of pavement, as is so often done to the exclusion of the other factors which have an important bearing on the problem.

With the number of factors involved, it is easily seen that a very large mileage of pavement must be gone over in order to get a sufficient number of examples in which the factors concerned are the same. This is a tremendous job and without the aid of modern mechanical means of sorting and assembling this sort of data, could nearly be classed as impossible. It is being attempted in Michigan, with these mechanical aids, and within a year's time we will know to a definite certainty as to just how much can be done with this sort of a study. It is a question of the use of a great many examples in order to show a definite trend of the average. For a long time to come it is doubtful as to whether or not any other solution of this particular problem is possible.

Acknowledgment.—The above paper was presented at the 15th Annual Purdue Road School, Jan. 21-25.

Turkey Proposes to Tax Women for Road Purposes.—A law is in preparation in Turkey making the road tax applicable to women between the ages of 17 and 65 as well as men. This tax is one which must be discharged either by the payment of a fixed sum or by labor.

Examination of Bituminous Macadam Pavements

A Method for Improving Their Quality

By J. E. BOYD
Testing Engineer, Georgia State Highway Department

IN constructing concrete pavements we consider it necessary to test the concrete and the finished pavement, although preliminary tests on all materials are made, and inspectors constantly watch proportions during construction. Likewise we require daily tests on sheet asphalt mixture, and samples from the pavement despite the fact that all materials have been tested and inspectors check every operation. Should not we then make post construction tests on bituminous macadam pavements? At present, the asphalt and stone are tested, and then testing stops. We know how the several courses of stone grade separately but do not know the grading of the combination of these several sizes, nor do we know how uniformly the asphalt is distributed.

Density and Asphalt Percentage.—Such matters as density and percentage of asphalt are seldom considered in connection with bituminous macadam pavements. The engineer usually insists upon the full thickness of stone specified, but is seldom concerned if the thickness runs above the required amount, thinking of course that the more stone placed the better the pavement will be, and that it is the contractor's business if he wants to put in additional stone without additional compensation. This, however, is a mistaken idea. If the quantity of stone is increased, the asphalt percentage will, of course, be decreased. The lack of uniformity in the distribution of the asphalt permits variations in the asphaltic content of the pavement that are already too wide and where the quantity of stone is allowed to run much above the specified quantity, there will certainly exist stretches of pavement containing an inadequate percentage of asphalt. Specifications permit a variation of from 2.55 to 2.95 gal. of asphalt per square yard for a 3-in. compacted thickness. If this minimum quantity is applied to a 3.75-in. thickness the percentage of binder is reduced 26 per cent below the quantity anticipated, or the average specified quantity for 3-in. thickness. Such a variation in proportions is permitted in no other type of pavement and I do not believe that engineers in general are aware of the necessity for exactitude in bituminous macadam construction.

A wealth of information may be obtained by testing samples from a penetration macadam job, as shown in the accompanying report, and we believe that with such information, construction details can be so handled as to make the bituminous macadam pavement a "sure shot."

Sampling Bituminous Macadam Pavements.—A block 12 in. square is marked off on the surface of the pavement, and cut out with the aid of a broad chisel or hatchet of tool steel driven by a sledge hammer. The sample is placed in a clean cloth bag and sent to the laboratory with information as to the accurate dimensions of the sample. Exact dimensions are essential to the accuracy of test results.

Method of Testing Bituminous Macadam Samples.—The sample is weighed in the cloth bag to the nearest ounce, and placed in a hot extraction apparatus for removal of asphalt.

An oven such as used in steaming cement pats for soundness test is made an ideal extraction apparatus by putting into the lid a copper coil for the circulation of cold water. The bag containing the sample is placed upon the screen, and about 3 gal. of carbon tetrachloride are poured into the oven. A flame under the oven evaporates the solvent which condenses on the copper coil and drops down on the sample to extract the bitumen. About four hours are required to extract the asphalt from the average sample.

After extraction is complete the sample is dried, and reweighed, and the loss in weight recorded as pounds of asphalt per square feet of pavement. The stone is then screened to ascertain the pounds per square foot of each size.

Method of Computation.—In order to explain clearly the methods of computation, an example is worked out below.

A sample 12 in. square and $3\frac{9}{16}$ in. thick, weighs 37.5 lb. After extracting asphalt the stone weighs 35.0 lb. The difference represents 2.5 lb. asphalt per square foot for $3\frac{9}{16}$ in. or 22.5 lb. or

$$\frac{22.5}{1.03\times 8.3} = 2.63 \text{ gal. per square yard}$$

for $3\frac{9}{16}$-in. thickness, which is equivalent to 2.22 gal. per square yard for 3-in. thickness.

The specific gravity of the asphalt is 1.03.

The specific gravity of the stone is 2.81 and weighs 85 lb. per cubic feet loose measurement.

Grading of Stone

	Lb. Sq. Ft. 3 9/16 In.	Lb. Sq. Yd. 3 9/16 In.	Cu. Ft. Loose In.	Lb. Sq. Yd. 3 In.	Cu. Ft. Loose 3 In.
Size No. 2	20.25	182.25	2.144	153.50	1.806
Size No. 4	8.75	78.75	.926	66.33	.780
Size No. 6	3.00	27.00	.318	22.74	.268
Size No. 7	3.00	27.00	.318	22.74	.267
Total	35.00	315.00	3.706	265.31	3.121

One square yard 3 in. thick is equivalent to 2.25 cu. ft.

The total weight of 1 sq. yd. of finished pavement 3 in. thick is

$$\frac{37.5\times 9\times 3}{3\frac{9}{16} \text{ in.}} =$$

284.2 lb. and 1 cu. ft. weighs 126.3 lb., or the finished pavement has a specific gravity of $\frac{126.3}{62.5} = 2.021$. 3 in. of pavement contain per sq. yd. $\frac{22.5\times 3}{3\frac{9}{16}}$ =18.95 lb. a. c. which occupies

$$\frac{18.95}{1.03\times 62.5} = 0.2945 \text{ cu. ft.}$$

$$\frac{.2945}{2.25} = 13.09 \text{ per cent asphalt by volume.}$$

Comparison of Fine Samples from Three Different Projects of State Highway Board of Georgia Laboratory

	1 Proj. 413-B	2 Proj. 422-D	3 Proj. 422-D	4 Proj. 426-B	5 Proj. 422-D
Lb. Sq. Yd. 3 In.—No. 2 Stone	184.0	157.05	162.00	153.0	186.2
Lb. Sq. Yd. 3 In.—No. 4 Stone	56.0	61.2	58.14	71.1	41.4
Lb. Sq. Yd. 3 In.—No. 6 Stone	8.0	21.15	15.36	17.1	18.6
Lb. Sq. Yd. 3 In.—No. 7 Stone	5.6	12.6	9.55	13.5	11.6
Total Stone	253.6	252.00	245.05	254.7	257.8
Gal. A. C. Per Sq. Yd.	2.50	3.02	2.105	2.83	2.67
Sp. Gr. Pavement	1.955	1.976	1.872	1.98	1.996
Per Cent Voids Compact Stone	35.6	35.2	37.76	35.30	34.77
Per Cent Voids Finished Pavement	20.84	17.4	25.33	18.60	19.04
Cu. Ft. Loose Stone	2.984	2.965	2.883	2.996	3.035
Per Cent Compaction	24.6	24.12	21.96	24.9	25.87

Limestone, 2.80 specific gravity, was used on each project and considered to weigh 85 lb. per cubic foot loose.

Note very close checks on total quantities of stone except in case of No. 3, in which case no doubt the compaction is inadequate. Some of the stone chips have been removed from the road by traffic and the total amount of stone used slightly exceeds the quantity shown above. Perhaps 258 lb. total per square yard is nearer correct than 254 or 3.04 loose cubic feet per square yard or 8.88 sq. yd. per cubic yard of loose stone.

Note also the lack of uniformity in the distribution of asphalt and the lack of uniformity in gradation of stone.

A square yard of solid limestone 3 in. thick weighs $\frac{2.81 \times 62.5 \times 27}{12} =$ 395.2 lb.

$\frac{395.2 - 265.3}{395.2} = 32.88$ per cent voids in compacted stone.

32.88—13.09=19.79 per cent voids in finished pavement. 1 sq. yd. 3 in. thick contains 3.12 cu. ft. loose stone.

$\frac{3.12 - 2.25}{3.12} = 27.88$ per cent compaction of stone.

Profit or Loss on a Contract

Some Ways of Increasing the Profit on a Job

By D. H. DICKINSON
Consulting Engineer, Boston, Mass.

AT this time of the year with income tax reports fresh in mind most of us are aware within a reasonable degree of accuracy how we stand in the realm of business for the year 1928. In pondering upon this situation we are confronted with two direct questions: Does the record of the year's business show a satisfactory return for our efforts during this period, or do we find ourselves journeying along the red ink route toward business mortality? The answer in each case can be readily ascertained, but the reasons therefor may not be quite so evident, unless perchance our business records have been kept sufficiently in detail to readily indicate where a profit was secured, and also where losses were sustained. Such records when available are not only of high analytical value, but are also of great assistance in figuring future work of similar character.

In some few instances losses in part may be charged directly to lack of experience, in which case it should be remembered that experience like any commodity must be purchased and paid for with legal tender, or its equivalent, but when once acquired is an asset no less than equipment, or capital as such should be made to produce dividends.

We occasionally hear the remark that there is no money in this, or that business, and sometimes this remark is directly applied to road contracting. In this connection you are referred to the accepted saying, that any legitimate business for which there is a demand can be made profitable if properly and intelligently conducted, and surely there is a demand for perhaps the greatest business in the country, that of road building. It is therefore my belief that it can be made not only profitable, but even more so through strict adherence to the principles of modern business.

Applying Modern Business Principles to Road Building.—The road builder in common with other manufacturers agrees to deliver a finished product in conformity with certain standard requirements, involving the use of labor, machinery and materials. It is important therefore first of all that he should gauge correctly the cost of these several ingredients, as no one can logically anticipate profits from his business if he undertakes to perform work for less than actual value.

I recall many years ago the statement of an old time contractor that he was primarily interested in figuring a job so as to secure the contract, and that he then trusted to luck that something would turn up during the process of the work that would be in his favor, and of sufficient importance to net him a reasonable profit.

Doubtless it was "old timer" who first caused the business of contracting to be likened to a game of chance. To a certain degree it does contain this element, but the same classification applies equally well to every other business enterprise. We all expect to take in more money than we pay out, and must continue to do so in order to exist. The element of risk is always present in every line of endeavor.

Generally speaking the fundamental principles of business are to a large extent interchangeable, and what is considered sound business judgment in one line of work applies equally well to other lines. It is a reasonable assumption that a man who has been conducting a business for a period of years has a better understanding of his own affairs than an outsider, and yet it is equally true that in some cases men stand too close to their work to obtain a proper perspective. Their time is often so taken up with the duties of management and financing that certain details, which have a direct bearing on the pay estimate, are apt to be overlooked.

Factors Affecting Profits. — In your work for the past season let us assume that your bids were prepared with much study and forethought, and that proper allowances were made for your fixed charges. Yet in spite of all these precautions it is possible that some of your work did not show the profit which you had every reason to anticipate. Leaving aside the fundamental principles of business management which are well understood, and omitting such other factors as can not be accurately predetermined, but which nevertheless have a direct bearing upon the receipts, such as the weather, the labor market, sudden shortage of materials, delays resulting from breakdowns, and a host of others with which every contractor is familiar, let us consider some equally important and effective factors which appear at times to be entirely overlooked.

The profits of a contracting business can be greatly influenced through cooperation, or the lack of it between the contractor and the engineer in charge, and one of the contractor's chief aims on every job should be to establish cordial business relations with the engineers with whom he comes in contact on the work. The principles of fair play when practiced by both parties to the contract result not only to their mutual advantage but to the advantage of all concerned.

The engineer is assumed to be an arbiter who has at heart the interest of the contractor as well as that of the party of the first part, and it is not expected that he will exact the pound of flesh in his dealings, although instances have occurred where the engineer, imbued with a surplus amount of zeal, or for some other equivalent reason has lost sight of this important relation, and with telling effect upon the contractor's profits.

Effect of Arbitrary Decisions.—Often the profits are still further influenced by the manner in which a contractor is required to perform his work through arbitrary decisions not always in accordance with his contract.

In the conduct of his work it is the contractor's rightful privilege to secure the greatest profit consistent with the terms of the specifications, and he should make it a point to understand thoroughly the specifications requirements, not only before he submits his proposal, but also during the progress of the job.

We sometimes hear discussions relative to the interpretation of specifications. When properly written they require no interpretation, and they permit of such only in case of conflicting provisions, or ambiguity, and in such instances it is generally only fair that the contractor should receive the benefit of any doubt.

The Field Measurement of Quantities.—On the usual highway contract in this locality, many different items of work with their corresponding unit prices are involved. The extent and value of certain items as they appear on the final estimate can be ascertained with a little difficulty. There are other items, however, such as ledge and earth excavations, borrow and gravel, which the contractor generally fails to verify, accepting often with more or less misgivings the amounts as they are rendered.

It sometimes occurs that the field measurements for such items are taken by men inexperienced in construction detail and the quantities calculated by others equally unfamiliar with construction work, and while their intentions are above criticism, yet in the determination of quantities for such important items the element of judgment should occupy a prominent place, and judgment when not based upon actual and sufficient experience and knowledge of the work is not of the highest value.

With the keen competition that exists in highway contracting each and every contractor should be continually alert

to guard against business leaks, and he is especially advised to take the time to verify, to a reasonable extent at least, the quantities not only in his final estimate, but in the partial payments which he receives periodically.

In this paper I have attempted to point out some of the ways by which a contractor may increase his profits or reduce his losses. The bid may be prepared with much care and study, and in fact may be an entirely reasonable one, yet in the conduct of the work through lost motion, lack of cooperation with the engineer, failure to purchase materials shrewdly, neglecting to take advantage of discounts, or through failure to understand thoroughly the specifications, perhaps by performing work and not receiving payment where through oversight, or otherwise, no definite basis of payment was specified, or through failure to verify the quantities in the pay estimate, the contractor may be deprived of a portion of his legitimate profits, which he might perhaps have secured had he devoted a little more attention and forethought to these important details.

Acknowledgement.—The foregoing is a paper presented March 27 at the annual meeting of the New England Road Builders Association.

Traffic Volume Studied in Pennsylvania

Sections of Pennsylvania state highway carrying the greatest volume of traffic, and the annual daily averages of these sections, as computed from the 1924 data and estimated for 1929, follow:

As observations extending over a period of years in a number of states show that the volume of traffic varies almost directly with the increase of motor vehicle registrations, the average density of Pennsylvania state highway traffic is estimated to increase approximately 45 per cent. From 1924 to 1929, and estimate of future registrations of motor vehicles in Pennsylvania, indicates a 30 per cent average increase of traffic from 1929 to 1935.

Route Nos.	Approximate Mileage	Highway Section	Annual Average Daily Motor Vehicles 1924 Computation	1929 Estimate
No. 1	7	Philadelphia-Media	7,171	12,270
No. 30	3	Philadelphia-Bryn Mawr	6,929	10,442
No. 30	6	Bryn Mawr-Wayne	5,407	9,251
No. 263	6	Philadelphia-Willow Grove	4,626	6,971
No. 13	10	Philadelphia-Chester-Delaware line	4,522	7,737
No. 11	17	Wilkes-Barre-Scranton	4,007	5,506
No. 1	13	Philadelphia-Morrisville	3,744	5,343
No. 30	14	Wayne-Junction with Route 147	3,357	5,388
No. 220	4	Altoona-Hollidaysburg	3,330	4,922
No. 30	6	Pittsburgh-East Pittsburgh	3,272	4,970
No. 19	5	Pittsburgh-Bridgeville	3,253	4,941
No. 5	6	Philadelphia-Junction Routes 133 and 225	3,171	4,757
No. 22	13	Reading-Womelsdorf	3,067	4,472
No. 22	6	Allentown-Easton	3,066	4,758
No. 11	11	Scranton-Factoryville	3,002	4,014

Shoulder Treatment in California

A low shoulder or rut along the edge of a pavement is a constant source of danger to traffic and a never ending annoyance and expense to the highway maintenance organization. How this problem is handled by the California highway department is summarized as follows by T. H. Dennis, state maintenance engineer, in the 6th biennial (1927-28) report of the Division of Highways:

Every effort is made to keep the shoulders flush with the pavement, but with only fair success. Earth dusts up and blows away when dry and ruts immediately when wet. Sand is very unstable and the rock in waterbound material breaks loose under traffic and can not be repaired satisfactorily except by reworking the entire shoulder. Oil treatment of the shoulder material is a somewhat expensive type of betterment and requires excellent maintenance but, so far, is the only solution of the problem that renders good service.

Sandy shoulders are treated by blading off the top 2 in. and applying 1 gal. of medium fuel oil to the square yard of surface. The oil is mixed in by harrowing thoroughly. The top 2 in. is then bladed back and another gallon of fuel oil per square yard is applied and harrowed in. A drag is then worked along the shoulder until the material is thoroughly set and compacted.

Well bound rock shoulders are sealed by the application of a tack coat of ½ gal. per square yard of light fuel oil after the surface has been swept clean of dust and the rock exposed. After the tack coat has penetrated, the shoulder is brought up flush to the pavement with clean rock and road oil, having 90 per cent to 95 per cent of 80 deg. pentration asphalt, is applied at the rate of ⅜ gal. per square yard of surface and covered with clean screenings.

Loose rock shoulders are mixed with medium grade fuel oil following the mixing method as developed for oil mix road surfaces. Shoulders are treated for a width of 2 to 5 ft., depending on traffic needs and funds available, particular attention being given shoulders along the older 15-ft. pavements.

Highway Markings Guide Air Pilots

Aeroplane markings on Pennsylvania's main highways have proven useful to cross-country flyers and have won the commendation of army aviators. Captain Frank H. McCaffrey, Operations Officer, of the 324th Observation Squadron of the U. S. Army, in a letter to James Lyall Stuart, Secretary of Highways, states: "These route numbers attracted attention from an altitude of 2,000 ft. and were easily read from 5,000 ft. This is very helpful to cross-country flyers." The markings are placed at intervals of 10 miles, on straightaway stretches of road, and are inverted every 10 miles, alternating letters "E" and "W," which designate east or west. The markings contain the legend number of the highway; for example, the Lincoln Highway is marked in white letters, 14 ft. high, as "U. S.—30," with an arrow designating the east or west direction.

National Highway Organization in Italy.—By Decree No. 1094 of May 17, 1928, the Italian Government formed the "Consiglio di Amministrazione dell'-Azienda Autonoma-Statale della Strada" (Administrative Council of Autonomous State Highway Institute) for the purpose of maintaining a greater control over the construction repair and maintenance of the national highway system, which has been done by placing the institute under the supervision of the Ministry for Public Works. This organization became necessary in order to carry out effectively the government's national highway projects in various parts of the country. The first annual program for the construction and repair of the national highways by the institute consists of 1,600 kilometers, of which about 501 are located in the Rome consular district. Operations were commenced during the latter part of 1928 and now about 25,000 men are employed on these projects.

Government Statistics of the Cement Industry for March.—The ratio of the operations to the capacity of the American portland cement industry during the month of March was 47.4 per cent, according to figures released by the Bureau of Mines of the Department of Commerce. During the month 9,969,000 bbl. were produced, 10,113,000 bbl. were shipped, and there were in stocks on hand at the end of the month 29,727,000 bbl. Production in March, 1929, was 2.5 per cent less, and shipments 0.2 per cent less than in March, 1928. Stocks at the mills were 8.3 per cent higher than a year ago.

The Major Problems of Locating State and Federal Aid Roads

Present and Anticipated Future Needs Must Be Considered

By A. R. LOSH

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IT is recognized that the detail problems of highway location depend upon the peculiar conditions of the individual project. Equally so it is true that there are general problems on roads of the same class but these may be decidedly different for roads dissimilar in their uses. Thus different governing conditions apply in the location of roads for sectional and interstate traffic than do for local roads serving small agricultural communities. Roads located primarily for parkways, pleasure drives and for recreational purposes where scenic considerations are of major importance will naturally impose conditions differing from those of the other classes. There is, however, one fundamental principle which we believe should be the controlling feature in any road location. Briefly this is that the resulting location should be adequate for the present and prospective future needs of the highway. The present needs are readily determined; the future needs require the exercise of judgment and foresight.

Errors in Location Costly.—The reconstruction and improving of roadway surfaces and structures can be readily justified from the standpoint of prolonged usage or of needed increased facilities in the same way as the rebuilding and remodeling of homes, office buildings, mills and other structures, but the relocation of a large portion or all of the road does not present a similar case. This change of location involves a substantial loss of the right-of-way, roadbed and structures as well as the expense of their reproduction on the new line. It is difficult to find suitable explanation or justification for the building by the present generation of many of its main highways three times and on three different locations.

It is not to be understood that the mistakes in location in the past rest solely upon the highway engineer, for this is not the case. Many of our earlier improved roads were not located but merely followed land lines or existing rights-of-way of older roads. The engineer was given little or no opportunity to develop a suitable location. Road funds were provided by local governmental units and the roads placed on locations acceptable to the governing boards or commissions. Most of the present lines of travel were originally only local roads and the subsequent traffic development was not anticipated. This condition no longer exists except for the local roads. The main highways are financed by the road user at large, by the state and by the Federal government. The engineer should approach the location problem with the future uses of the road in view and endeavor to provide a location which will be suitable for this purpose. This will include in addition to alignment, grades, stream crossings and similar engineering works, the provision for future development of the highway and its protection from encroachment by industries and other utilities. Briefly the mere located line without adequate right-of-way and roadside protection will not be sufficient.

It will be the writer's purpose to discuss the major problems of locating state and Federal aid highways. The engineer has received very little assistance on highway location from engineering textbooks. The subject is discussed only briefly if at all, and then usually on the assumption that the existing road will be followed with only minor changes in alignment. The location of highways purely as transportation lines is not the usual practice. This is not a condition readily attainable nor is it strictly desirable on public highways. The service of the project in the highway plan as a whole is the consideration which should be followed.

Effect of Emphasizing Local Needs.—There are still some who would consider the present highway building as primarily of local importance and for the immediate local needs, it being proposed at some future time to build a system of through highways on more direct lines. Such a line of reasoning has been followed to a considerable extent in the past with the following results:

(a) The location of important through highways has been materially affected by purely local considerations.

(b) Frequently local and through traffic were combined where a separation would be preferable.

(c) When reconstruction for the through traffic is undertaken it is exceedingly difficult to make adequate relocation.

(4) When the indirect line is used a number of years, development along it results in increased property values which may be seriously impaired by substantial changes in location.

(e) Right-of-way changes resulting from relocations are usually more expensive than if made under the original construction due to increased property values and damages to improvements.

(f) The value of the old road, in right of way, roadbed, surfacing and structures, is a loss unless the road can be used advantageously for local purposes. But even in this case it must be considered that one mile of main highway costs as much as several miles of serviceable local roads and there is a loss in changing a main road to a local one.

(g) The roadbed structure consolidated and compacted by years of use is lost for reconstruction purposes.

It is this line of reasoning which would make the work of the engineer follow the development of the country rather than lead and materially aid in that development. It is the line of least resistance, of temporary expediency and of future changes with attendant losses. The aim of the engineer should be to provide a location which will remain as a major line of highway transportation and so planned to meet the requirements of the future. A location of this character approaches the "permanent road" feature as nearly as it is humanly possible to do so.

Controls to Be Considered.—On all highway projects there are administrative controls or restrictions which determine at least the general location of the project—or the route of which it is a part. Thus the termini of the project are predetermined and the intermediate location may or may not be fixed. These restrictions will occur under the following classifications:

1. Major control points of the Federal aid system determined by the Secretary of Agriculture and the state highway departments and subject to modification by joint action.

2. State highways and control points designated by state highway commissions under legislative authority.

3. Control points for state highways fixed by legislation.

4. County or road district bond issues used for a portion of construction cost may require a definite location to be followed.

Under conditions 1 and 2 there are opportunities for a general engineering study before the controls are specified and also for a revision of controls based on further engineering investigations. Condition 3 may or may not be based

on engineering investigation or permit some departure from the established route at the discretion of the state highway commission. Condition 4 presents the greatest difficulty as frequently where local funds are contributed the detailed location is fixed to serve local wishes primarily. The writer has known of cases where the increased cost of these features placed by local influences was greater than the local funds provided. A recent case of this kind occurred in Jefferson County, Okla., where county funds were provided to aid in the construction of U. S. Highway 81 on a location determined by the county officials. This location involved three more railroad intersections, one additional bridge and some increase in distance over a location selected by the state highway commission and the Bureau of Public Roads.

This system of financing has been responsible for most of the unsatisfactory locations in the southwest during the past 15 years. Where it is necessary to continue this system of financing, in fairness to all parties concerned, the location should be determined in advance of the local arrangements for financing.

Even under control conditions 1, 2 and 3 there is too great a tendency to follow existing lines of improvement with relatively unimportant control points established; while under condition 4 this often reaches the point of affecting the detail of location. Regardless of how the conditions are imposed they may in effect restrict the work of the locating engineer to mere details of design. Administratively, controls are necessary and in the writer's opinion should be general in character and limited to the following conditions:

A. A town or city located on or near the general line of the route between adjacent control points of the route.

B. A town or city of sufficient importance to be a terminal point for the traffic passing between the adjacent controls.

C. A junction point, preferably near a town or city, of several highways for the distribution of traffic.

D. Topographical features based on engineering investigations.

Economy Governs Within Controls.—Within the limitations established as controls the engineer should so far as practicable determine upon an economic location considering at their relative weights both through and local traffic. This selection will be the line which will provide the long-run least cost, including construction, maintenance and traffic operations. The shortest line will usually be the economic location for the reason that practically all items of cost except earthwork and structures vary directly with the length of the line. In a country of broken topography the cost of earthwork and structures may be much less on the longer line but the other items of construction, and of maintenance and operation, will usually determine the location. Local traffic can usually be served cheaper by lower priced lateral spurs from the main line than by attempting to give direct service.

One of the usual problems before the engineer is whether or not to swing the main line from its direct course in order to give highway service to an intermediate point such as a small town or community. Theoretically the problem can be solved by estimating the cost of construction, maintenance and operation for each of the two possible layouts, i. e., the main line direct with a lateral spur and the main line on indirect location through the intermediate point.

A similar problem is that of combining two or three highways for some distance out from the city in order to reduce construction mileage. While economically desirable, frequently this involves the questionable practice of encouraging traffic congestion at junctions and terminals.

Studies of state highways show a substantial volume of traffic outside the purely local class. Thus the California studies of 1922 show the average length of truck hauling to be 31 miles and of passenger buses 41 miles. The Pennsylvania studies show 43.8 per cent of the state highway traffic travels 50 miles or more and for the Ohio study this figure is 30.3 per cent. Similar data are not available for the state highways of the southwest, but it is believed a larger percentage of long distance movement exists.

Traffic of this character is benefited more by the possible economic operation over the whole line than by the detail location through small communities with which it may have little or no contact. This provides the basis for considering the needs of local and through traffic separately. It is recognized that grades, character of road surface, alignment, traffic hazards and conditions causing loss of momentum, use of brakes and extra wear on the machine are all factors affecting adversely the cost of traffic operation but the data are not available in a form to be readily used.

Topography Demands Consideration.—In working out the detail location further economies can be made by taking advantage of topographic conditions, soils, available local material or railroad facilities for importing materials. Approximately 4,000 tons of materials are required per mile of 18-ft. concrete pavement. An increased dead haul of one mile will increase the cost of the road about $1,000 per mile. In addition to this there will also be the cost of moving on and off the job; also the hauling cost of materials for use in structure. The use of longer radius curves reduces the total length of line and the amount of surface widening. For a change in direction of 90 deg. a curve of 1,000-ft. radius gives a line 214 ft. shorter than a 500-ft. radius. Including widening the 500-ft. radius curve would require 938 sq. yd. of additional pavement.

Topographical conditions affect the details of location and in some instances are major controlling factors. Soils which are unsuitable for subgrades, shifting blow sands and rock classifications are all to be avoided if practicable. Overflow sections require high embankments with costly structures; for this reason valley locations are frequently undesirable. Stream crossings must be selected with the view of reasonable permanency of the banks, suitable foundations and required span length, and must be within the general location. Grades and curves adjacent to bridges should be reduced to the minimum. It is desirable to have a tangent of at least 150 ft. at each end of a major structure and also a light or flat grade. These conditions permit the driver to adjust his machine into the bridge alignment. Grades have probably received ample consideration in the past or probably more than other features. Considering the motor vehicles now in use on our highways some sacrifice of grade can be made to improve alignment. Short grades as high as 8 per cent can be taken readily by modern motor vehicles but continuous grades of more than 6 per cent are objectionable. Tangent profile grades are not particularly advantageous and do not justify increased expense. A rolling profile fitting the topography is less objectionable for night driving due to the headlight glare on tangent grades.

Grade separations at railroad intersections are desirable but not always possible financially. Where grade crossings are adopted the line should be located so that future separation can be developed, and in all cases approach curves and grades should not restrict sight distance.

The Problem in Cities and Suburbs.—Restricted areas in and near cities are frequently obstructions to direct highway location. This includes parks, golf courses, institutional reservations, cemeteries, railroad yards and airports. Generally it is impracticable to pass through these areas and the location must be carried around them. The location should give access to railroads and airports but be sufficiently removed to permit full operation of all facilities without congestion. A location directly adjacent to the railroad may be congested by trucks loading and unloading at the railroad and also by industrial spur tracks being constructed across the highway. Location along the railroad is usually adopted because it is desirable from engineering features and for the further reason that right-of-way is less difficult to secure. It has the further disadvantage of pro-

viding for development on only one side of the highway whereas, if removed a fourth of a mile or more from the railroad, property on both sides of the highway would develop.

One of the major problems of the locating engineer is to provide suitable locations into, through and around towns and cities. It is necessary to provide suitable connections into the street system of the city. It is also highly desirable to have a direct through connection even though it may be congested by city traffic in order to take care of through traffic making a temporary stop in the city. A belt line or by-pass location is equally desirable for the through traffic to avoid the city congestion in reaching its destination and to permit the sorting or segregation of traffic for different locations.

The desirable condition for the urban approach would be connections which would permit the distribution of traffic to (a) the retail section, (b) the wholesale and industrial sections, (c) railroads and airports, (d) several residential sections and (e) other highways by direct connections outside the city proper.

There are many town and city officials who believe that the highway should be considered as a continuation of "Main Street" out into the country and that it should be carried through the principal thoroughfares of the city. This is especially true of cities under 10,000 population and the smaller the municipality the more insistent it is, as a rule, that the highway pass through the main streets. The larger cities have their local traffic problem and as a rule are glad to secure any relief possible by routing through traffic over outlying streets or through the suburbs. In a great many cities, however, highways are taken directly through retail sections where the streets are congested with trolley cars, motor vehicles and pedestrians. There are numerous street intersections, sharp curves, grade crossings, congestion due to parking and other hazards of city traffic. The through traffic is delayed and local traffic congestion is increased, with possibilities of accidents multiplied. Too many towns and cities are placing restrictions on through traffic by means of speed ordinances, stop signs, signals and other regulations. These measures in most cases are necessary for the local traffic but the through traffic can better operate without them and outside the city.

State Highways in Cities.—The following Table I gives information on several highways through cities of the southwest.

The development of proper approaches to cities with arterial routes for traffic to and from the city and belt lines for traffic distribution requires the cooperation of state, county and municipal authorities. It also requires a careful traffic study and analysis, upon which can be based the present and future plans for improvements. The plan of highway improvement in the Cleveland regional area is an outstanding example of this character of work. As a result of this survey the city of Cleveland and its contiguous territory have developed a plan of major road and street improvements for ten years ahead and may proceed with individual projects, knowing their final position in the broader plan.

Curves.—Increase in most of the present speed limits appears inevitable. The engineer should anticipate this with provisions in his location to meet the conditions. Greater sight distance on horizontal and vertical curves is desirable. Six hundred feet is not excessive. Where this cannot be obtained extra width of surfacing is desirable. In the level and rolling country of the southwest, engineers are providing horizontal curves of 4 deg. and less. This makes extra width unnecessary, very little superelevation is required and, as previously stated, line length is reduced. The older practice of placing changes in alignment at the top of hills has been discontinued. It is considered a hazard to traffic. Other conditions being equal, curves should be placed where they may be readily seen by the approaching driver.

Width of Right-of-Way.—To a great extent engineers have allowed right-of-way considerations to influence location. This is especially true in those sections where the section line road system prevails. It is seldom that on rural highways more than 80 ft. of width is secured, which amounts to approximately 9½ acres per mile. Considering the cost of state highways at about $30,000 per mile there could be a justified expense of $3,000 per acre for a proportional reduction in length of construction. This does not take into consideration any savings in maintenance and operation costs.

The width of right-of-way needed depends upon the future requirements of the road and also the means for its protection from encroachment and exploitation. Few states have adequate laws regarding right-of-way acquisition and roadside protection. A recent Texas statute permits the state to obtain 100 ft. for a state highway which ordinarily is ample. There is nothing, however, to prevent the abutting property owners from building garages, service stations and other roadside establishments on the property line and utilizing a part of the highway for the transaction of their business.

Until such time as adequate legislation is enacted placing roadside development under the supervision of highway authorities the engineer should use such means as are available to protect and preserve the highway for its complete utilization. To this end the writer suggests the following measures: Acquire sufficient right-of-way for future development of the highway; obtain extra widths at all road intersections and other strategic points where roadside enterprises would likely be established. In making acquisitions it will usually be possible to retain in the right-of-way the narrow strips, gores and other small parcels of land cut off from the original tract. These parcels may be utilized for highway purposes in the future or for roadside planting and beautification. In any event they are not available as sites for billboards and roadside establishments. Through areas of natural beauty either obtain in fee or protect with long-term leases several hundred feet of extra width each side of the right-of-way. The in-

Table I—State Highways in Cities

City and Highway	Miles in City	Sharp Curves: Number	Sharp Curves: Total Degrees	Railways (All Classes): Number, Tracks Crossed	Railways (All Classes): Route Used by Street Railway Per Cent	Street Intersections: Control Signs, Signals, Police	Street Intersections: Total Number	Speed, Legal Miles per Hour
Dallas—								
U. S. 80	8.5	12	735	19	12	15	89	10-20
U. S. 75	7.6	8	870	26	16	16	119	10-20
Fort Worth—								
U. S. 80	10.9	6	390	9	51	12	123	12-18
U. S. 81	9.25	11	1,150	27	77	7	111	12-18
Houston—								
U. S. 90	8.5	14	780	9	4	13	110	8-20
Little Rock—								
U. S. 65	4.5	4	525	7	19	4	40	15-35
U. S. 67	5.0	6	515	7	15	4	56	15-35
U. S. 167	3.3	2	180	7	6	4	35	15-35
New Braunfels—								
U. S. 81	3.2	9	635	1	0	0	30	20
Oklahoma City—								
U. S. 77	6.2	6	510	21	9	6	70	25
U. S. 66	4.15	3	330	4	40	4	42	25
Purcell, Okla.—								
U. S. 77	1.2	4	360	4	0	1	13	
San Antonio—								
U. S. 81	10.0	14*	1,200*	8	28	13	84	10-20
U. S. 90	8.6	9	845	23	55	12	95	10-20
San Marcos—								
U. S. 81	2.2	6	390	0	0	0	32	20
Tulsa—								
U. S. 66	9.1	8	591	22	4	7	97	8-25
Waco—								
U. S. 81	4.2	3	360*	25	33	7	39	15-20

*Other routes give less curvature but more traffic congestion.

terest of civic organizations and public-spirited citizens should be encouraged and their aid secured to obtain the desired ends.

It is apparent to everyone that aside from the commercial features of highways there are social and political considerations which cannot and should not be disregarded. Roads are for public usage and must be located, constructed and maintained with that end in view. Whether for business or for pleasure the public travels to definite points of interest and attraction. Schools, churches and courts are the mainstays of the commonwealth. The public must have access to these institutions by highways. Rural mail and express deliveries, transportation of farm products and rural community life while usually served directly by local roads are affected by their connection with the main highways. There are patriotic shrines in every section of the country which should be made accessible from the highways. Our national and state parks and forest preserves are visited annually by thousands of our citizens and, with improvements in our roads, will be used by many more for recreational purposes.

As a function of the government, every governmental unit should be connected finally with the country at large. The writer has always believed that the larger unit of government has this obligation to its constituent parts. The Federal to the state, the state to the county and the county to its towns and communities.

These considerations of s c h o o l s, churches, courts and other conditions vitally affecting the citizenship of the nation cannot be weighed in terms of economics or engineering but must be taken under the "General Welfare" clause of our fundamental law.

Acknowledgment.—Mr. Losh's paper was presented on April 25 at the spring meeting of the American Society of Civil Engineers at Dallas, Tex.

New Plan for Road Construction in Guatemala.—The Minister of Agriculture of Guatemala is planning to build and maintain roads by the employment of men called for military service and working as a miltary organization. The minister has stated that inhabitants of certain portions of the republic of pure Indian blood objected to being called to the army and therefore, in times past, they had been granted the privilege of fulfilling their military service by working on government public projects. His plan is to have them get credit for military service by working on the public roads. A great many army officers, now on the reserve list, will be placed on active duty and put in charge of the road work, thus creating labor battalions, having a military organization, and discipline but under the direction of the minister of agriculture, under whose jurisdiction is the direction of roads.

Gravel Roads

Standard Grades for Gravel Mean Better Highways

By BEN. H. PETTY
Assistant Professor of Highway Engineering, Purdue University

GRAVEL has been used as a road surfacing material for a great many years and when properly selected makes an ideal surfacing material for secondary roads. The terms "gravel," however, has covered a multitude of sins. We must realize the fact that not everything coming out of a gravel pit is gravel. A deposit of this kind usually ranges from very fine silt to large stones 6 or 8 in. in diameter. In addition there is frequently included a liberal supply of clay which is of very little benefit on the road. This pit material does not run uniformly and loads hauled from one gravel pit may vary all the way from silt to boulders.

What Some Specifications Call For.—Even in this day and age some gravel road specifications merely state that the gravel to be used shall be secured from "so and so's" pit. Some specifications vary the procedure somewhat by stating that said road shall be constructed of "good" gravel. Obviously such specifications are worthless insofar as securing suitable road gravel is concerned. Who is to determine what is "good" gravel?

Frequently the sale of local gravel is influenced by political pressure and preferment to the detriment of the taxpayers. Thousands of miles of so called gravel roads have been constructed which are not gravel roads at all, but which should properly be classed as sand roads. It is a mystery why taxpayers will meekly accept a so called gravel road built out of material which is probably 75 or 80 per cent sand and yet pay just as much for this type of road as a real gravel road would cost.

Sand Roads and Gravel Roads.—To my mind sand is in reality worn out gravel. Therefore, why should we pay for placing worn out material on a road. Other than as a binder for the coarser pebbles, sand is of practically no value on a road carrying average county traffic. It is true that a sand road is better than a "dirt" road, however, it should not be classed as a gravel road.

The other extreme is the building of so called gravel roads out of material exceedingly coarse, containing stones up to a maximum size of even 3 or 4 inches. It is ridiculous to expect a satisfactory highway constructed with gravel containing such coarse material. A road of this kind will always be rough and exceedingly difficult to maintain. The road grader or drag will either jerk out these large stones, starting holes in the road or else the blade will jump over the protruding stones leaving a ridge of finer gravel across the road which tends to start corrugations.

Advantages of Properly Graded Gravel.—It costs a little more to get properly graded gravel for our highways yet the service realized will compensate for this extra cost. I maintain that no gravel should be placed on a public highway which will not pass through a 1-in. circular screen. This assures a smooth riding surface, easily maintained. Any pebbles that will not pass the 1-in. screen should be crushed to a passing size. It is unwise to waste these oversized stones as our gravel supplies are already running short in some localities. These large stones represent the hardest material in the pit and, when crushed and mixed with the other gravel, make excellent road metal.

As stated before, the very fine material is practically useless on a highway. It will either blow away or be washed off by rains leaving the pebbles behind to stand the wear and tear of traffic.

To secure an ideal gravel, properly graded from coarse to fine, it would be necessary to specify percentages on several screens. This is done in some states. However, I believe two screens can be used satisfactorily on county work. Some counties are using with considerable success a specification which calls for all the material to pass a 1-in. circular screen with not more than 30 per cent passing the number eight screen. This 30 per cent finer than the number 8 screen will furnish sufficient binder for the coarser pebbles and any excess is worthless. After all, the pebbles from the number 8 screen to the 1-in. screen must be depended upon to resist the wear and tear of traffic. The finer sand is merely a binder for these pebbles. I have inspected many new, so called gravel roads which would test 70 to 80 per cent passing the number 8 screen. Obviously, these are sand roads and not gravel roads.

When a gravel road is to be built, specifications should be so worded that the taxpayers will get what they are paying for. This applies equally to maintenance gravel.

Big Impetus Given Road Construction in England.—A big impetus will be given to road construction by the Government's decision to increase the classification grants for new roads and bridges out of the Road Fund from 50 per cent to 60 per cent for Class I and from 33½ to 50 per cent for Class II, as from April 1. It is estimated that the concession will amount to about $11,017,750 a year. Among other road schemes proposed for the next twelve months, the Surrey County Council is embarking on town planning schemes which entertain proposals for 88 new roads at an estimated cost of $22,143,000.

Interpreting the Traffic Census

Results of a Special Study of the Traffic Problem

By T. H. DENNIS
Maintenance Engineer, California Highway Department

THE purpose of the maintenance organization is to serve traffic. To fulfill this obligation the highways must not only be preserved in the best condition, but information as to the rate of development of traffic must be collected so that expansion of transportation facilities will be just ahead of traffic needs. With this end in view the maintenance department has made a special study of the traffic problem during the past two years.

While traffic counts taken each year in January and July provide records of existing traffic, any worthwhile recommendation requires an approximate determination of the traffic capacity of two, three, and four lane pavements, also an estimate of the probable increase in traffic on any given section of road.

Peak Hours of Traffic.—On every heavily traveled road there is a period in the morning and late in the afternoon when travel is heaviest. Our analysis of actual hourly records for all sections of the state showed that for nearly 90 per cent of the stations the traffic during the peak hour was from 9 to 11 per cent of the total traffic from 6 a. m. to 10 p. m. For practical purposes the peak hour traffic may therefore be accepted as 10 per cent of the 16-hour count.

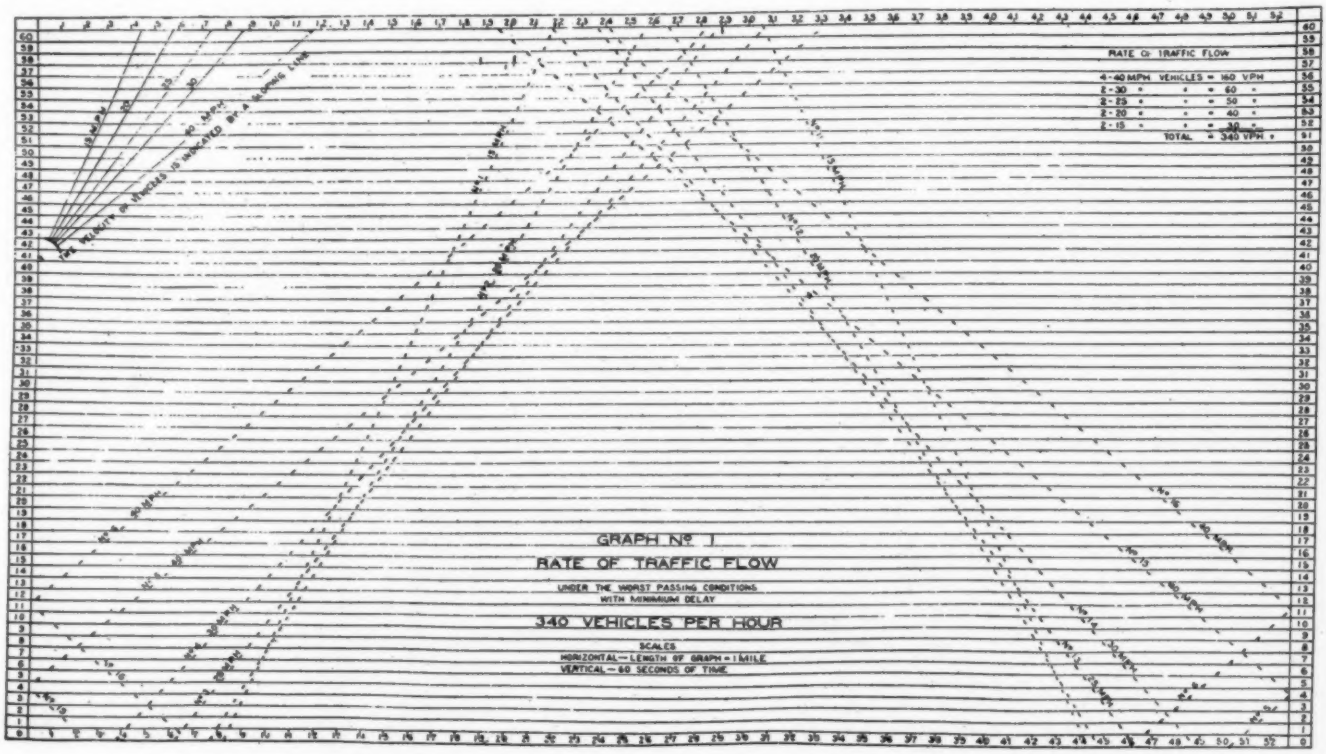
The next step was to determine the volume of traffic which might use the highway during the peak hour without undue interference. This quantity is influenced by a number of variables, such as condition of the road, alignment, intersections, range in braking distances, percentage of fast and slow vehicles, personal equation of each driver, etc. It is evident, therefore, that any figure adopted must be based on arbitrary assumptions. In making such assumptions in our study, consideration has been given to records of actual performance, experience and observation.

Capacity of Traffic Lane.—There are shown three tables which give the basic assumptions. Table I shows the number of vehicles which can pass over a single traffic lane at uniform rates of speed. In this table full braking distance is provided between each vehicle. The capacities shown permit 100 per cent safety for each vehicle.

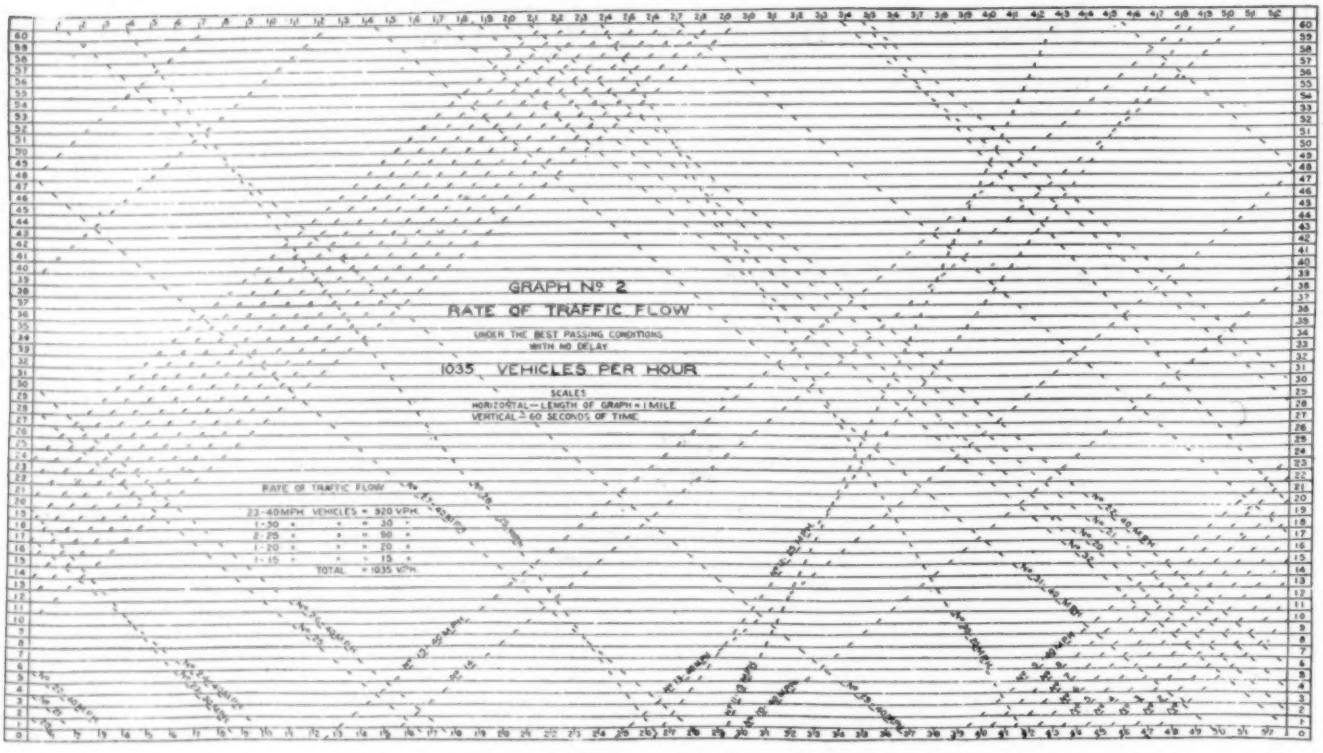
Table II shows what may be considered as the maximum capacity of a single traffic lane with all vehicles uniformly spaced and traveling at a uniform speed. No allowance is made here for braking distance. Table III is a combination of Tables I and II and represents an average volume at given uniform speeds. The capacities shown in these three tables are working capacities on the assumption that the opposite lane of the roadway is filled so there is no opportunity for passing and all vehicles are thus held at the speed of the slowest vehicle in the line.

Planning for Maximum Service.—The planning for pavement width to care for the estimated future traffic requires that the traffic capacity be taken at some definite figure. The range of driving speeds and other factors is so great that practical working capacities vary widely. At the expense of police control, increased danger of accidents and of delay, expense and inconvenience to users of the highways, traffic of 2,000 vehicles per hour may be passed over a single lane roadway at 20 to 25 miles per hour. However, a single vehicle traveling at a speed of two miles per hour would reduce the capacity of our single lane to 330 vehicles per hour. At 50 miles per hour it is theoretically possible to pass 2,400 vehicles per hour over this single lane in the same direction.

Alignment, gradient, proportions of


RATE OF TRAFFIC FLOW
4 - 40 MPH VEHICLES = 160 VPH
2 - 30 " " = 60 "
2 - 25 " " = 50 "
2 - 20 " " = 40 "
2 - 15 " " = 30 "
TOTAL = 340 VPH
GRAPH Nº 1
RATE OF TRAFFIC FLOW
UNDER THE WORST PASSING CONDITIONS WITH MINIMUM DELAY
340 VEHICLES PER HOUR
SCALES
HORIZONTAL — LENGTH OF GRAPH = 1 MILE
VERTICAL — 60 SECONDS OF TIME

Graph No. 1—Rate of Traffic Flow Under Worst Passing Conditions with Minimum Delay, 340 Vehicles per Hour


GRAPH Nº 2
RATE OF TRAFFIC FLOW
UNDER THE BEST PASSING CONDITIONS
WITH NO DELAY
1035 VEHICLES PER HOUR
SCALES
HORIZONTAL—LENGTH OF GRAPH = 1 MILE
VERTICAL = 60 SECONDS OF TIME
RATE OF TRAFFIC FLOW
23-40MPH VEHICLES = 920 VPH
1-30 " " = 30 "
2-25 " " = 50 "
1-20 " " = 20 "
1-15 " " = 15 "
TOTAL = 1035 VPH

Graph No. 2—Rate of Traffic Flow Under Best Passing Conditions with No Delay, 1,035 Vehicles per Hour

light and heavy traffic, weather, driving conditions, and the personal equation of different drivers all enter into the question of establishing a guide for the proper economical planning of roads for maximum service. The maintenance department has carefully considered these different phases of the problem in the light of traffic records and actual field conditions, and has arrived at the following capacities for the purpose of determining the width of pavement necessary to care for the estimated traffic in 1940:

	Vehicles per Hour
Two-lane roadway	700
Three-lane roadway	2,000
Four-lane roadway	3,200

These are considered to be the peak hour traffic figures and represent 10 per cent of the traffic for the 16-hour period from 6 a. m. to 10 p. m. This volume of traffic will permit fast traffic to travel at 40 miles per hour and provides for sufficient safe passing space for that purpose. It provides for a safety factor of about 30 per cent, that is: Traffic on a two-lane roadway can be increased to 1,000 vehicles per hour without serious delay. An explanation of the method of arriving at those figures is given below:

For Two-Lane Road.—Rate of traffic flow, with minimum delay, was determined under the worst and also the best combination of vehicle spacing and speeds. Graphs No. 1 and No. 2 were worked up to show these conditions. These graphs show the relative positions of the vehicles on a mile of two-lane roadway at each second of a minute interval of time.

Graph No. 1 shows a number of fast and slow vehicles equally divided as to direction of travel. At zero time vehicle No. 2 is just in position to turn out to pass No. 1 and vehicles No. 3, No. 4 and No. 5 are spaced at the closest interval so that no delay results as they continue their uniform speed. At the forty-eighth second, vehicles No. 2 to No. 5, inclusive, have completed

Table I—Minimum Capacity—One Lane

Miles per hour	(1) Braking distance (feet) (safe all grades to 6 pct.)	(2) Reaction time in seconds	(3) Reaction distance plus 17 ft. (from table II)	Spacing of cars, sum of (1) and (3)	Cars per mile	Capacity per hour
2	0.6	1.000	31.7	32.3	163.5	32.7
10	12.5	1.000	31.7	44.2	119.5	1,195
15	28.0	.938	37.6	65.6	80.5	1,207
20	50.0	.875	42.6	92.6	57.0	1,140
25	78.0	.812	46.8	124.8	42.3	1,057
30	112.0	.750	50.0	162.0	32.6	978
35	153.0	.688	52.3	205.3	25.7	900
40	200.0	.625	53.7	253.7	20.8	832
45	253.0	.562	54.1	307.1	17.2	774
50	312.0	.500	53.7	365.7	14.4	720

Table II—Maximum Capacity—One Lane

Miles per hour	Velocity feet per second	Reaction time in seconds	Reaction distance in feet	Reaction distance plus 17 feet	Cars per mile, one lane	*Capacity per hour
2	3.0	1.000	14.7	31.7	166.6	333
10	14.7	1.000	14.7	31.7	166.6	1,666
15	22.0	.938	20.6	37.6	140.4	2,106
20	29.3	.875	25.6	42.6	123.9	2,478
25	36.7	.812	29.8	46.8	112.8	2,820
30	44.0	.750	33.0	50.0	105.6	3,168
35	51.3	.688	35.3	52.3	100.9	3,531
40	58.7	.625	36.7	53.7	98.3	3,932
45	66.0	.562	37.1	54.1	97.6	4,392
50	73.3	.500	36.7	53.7	98.3	4,915

*Number cars passing given point.

Table III—Average Capacity—One Lane

Miles per hour	Cars per mile, 40 pct. of maximum, Table II	Cars per mile, 60 pct. of minimum, Table I	Cars per mile	Spacing feet	Capacity
2	66.6	98.1	164.7	32.0	329
10	66.6	71.7	138.3	38.2	1,383
15	56.2	48.3	104.5	50.5	1,567
20	49.6	34.2	83.8	63.0	1,676
25	45.1	25.4	70.5	74.9	1,762
30	42.2	19.6	61.8	85.4	1,854
35	40.4	15.4	55.8	94.6	1,953
40	39.3	12.5	51.8	101.9	2,072
45	39.0	10.3	49.3	107.1	2,218
50	39.3	8.6	47.9	110.2	2,395

their passing. At these speeds one-half mile of road is required to complete the passing without delay. In the meantime a similar spread of vehicles can be approaching from the opposite direction on the other lane with their passings complete in the same time interval. Vehicles No. 6 and No. 16 were then spotted at a spacing to give the least possible delay. It will be noted that these two vehicles must reduce speed at the fifty-eighth second because vehicles on the opposite lane prevent free passing. The addition of a single additional vehicle at any point will cause additional delay. This graph shows minimum delay and speed conditions which require maximum distance for passing. Twenty-four passings are made by 12 machines in the minute interval on the mile of road. The rate is 340 vehicles per hour.

Graph No. 2 shows a more nearly normal spread of fast and slow vehicles under the best passing conditions; 16 passings are made by 28 machines per minute on the mile of road. The rate of flow is 1,035 vehicles per hour. The average rate of flow shown by the two graphs is 688 vehicles per hour.

Three-lane Road.—Under the best conditions a three-lane road is capable of carrying twice the capacity of a two-lane road, or 2,000 vehicles, as the center lane is available alternately for fast traffic from either direction and the average speed would, therefore, be considerably higher than that of the slow vehicles. The inner lane is available to full capacity for 40 mile per hour traffic, or 2,072 vehicles, with a minimum of possibly 10 per cent additional on each of the outside lanes, or a total of 2,500 per hour. It is considered that 2,000 vehicles per hour during peak hours would be a reasonable capacity.

Four-lane Road. — With four-lane traffic, under proper police regulation, the outside lanes carry the slow moving traffic and the inside lanes the fast traffic. Under these conditions the two inside lanes will carry 4,144 vehicles at 40 miles per hour, according to Table III. With a minimum of 10 per cent additional for the slow traffic on each of the outer lanes, a peak hour traffic of 5,000 vehicles should be possible under well controlled conditions and our assumption of 3,200 as a working basis is considered a comfortable peak capacity.

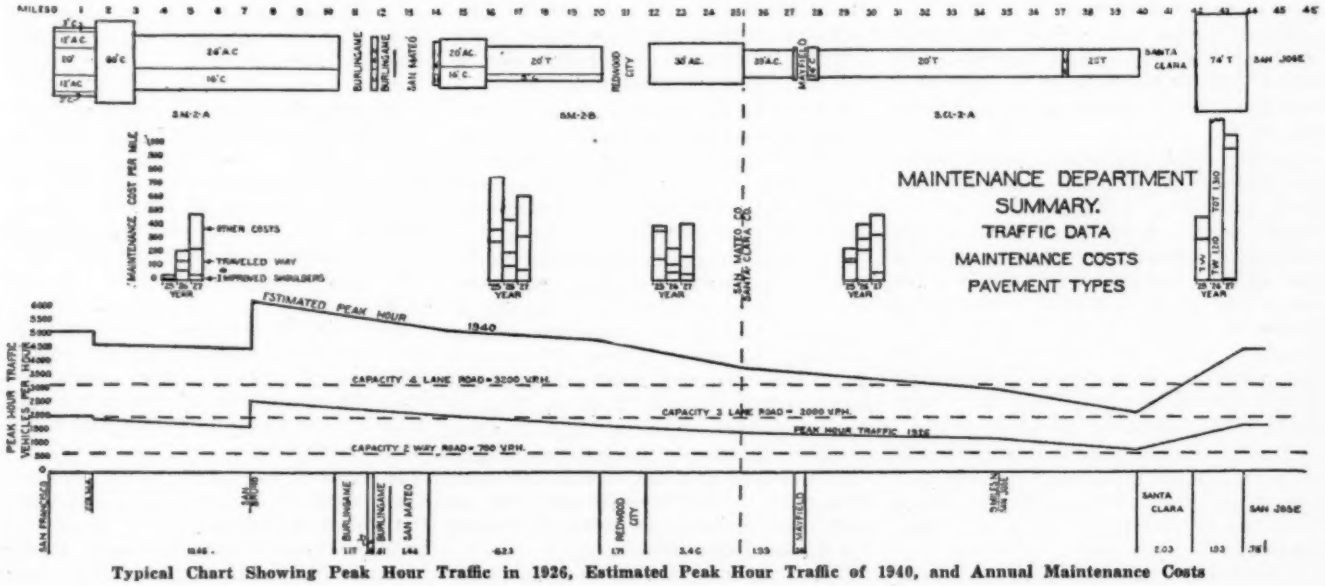
Consideration was also given to rate of traffic increase. This is dependent on increase in population, increase of vehicles in proportion to population, increase in traffic from outside the state, and increased use of vehicles as the highways are improved. For our purposes, after analysis of existing data in the above respect, it seemed reasonable to assume that the increase in traffic would continue at the present rate of nearly 9 per cent annually for the next 12 years without extreme change. Traffic assumptions as of 1940 were worked out on an average of 9.6 per cent annually over the 1926 count.

The information developed was applied in a practical manner, as shown by the accompanying typical chart. This chart shows the 1926 peak hour traffic; the estimated peak hour traffic of 1940, and the annual maintenance costs per mile of the various types of pavement; as well as the pavement and shoulder widths on a given section of highway.

Similar charts have been prepared for the entire state highway mileage and represent a summary of pavement types, maintenance costs and traffic records and needs, which makes this information easily available for analysis in connection with planning improvement in the work of the maintenance department.

Acknowledgment.—The foregoing is taken from the March-April California Highways and Public Works, the official publication of the Division of Highways of the State Department of Public Works.

Automobile Highway from Verona to Vicenza, Italy.—It has been ascertained through the Provincial Council of Vicenza, that plans have been approved for the construction of a new auto-highway from Verona to Vicenza. The plans have now been completed by engineers and the work is soon to be started. The new road will have a length of 31.6 miles and will in the main follow the present route, though cut offs, etc., are included in the plans. The road will be a connecting part of the trunk military auto road from Turin to Trieste. The plans for the road as presented to the Provincial Council of Vicenza by the Chief Engineer, A. Saccardo, are as follows: Length, 31.6 miles; width, 8 meters of center roadway, 1 meter bank on each side. The road will be constructed of concrete and the base, super-imposing the fine grade, will be of crushed stones. The graded sides will be composed of rock fragments, agglutinated together by cement. The crown will be at a gradient of meters 0.10 to meters 10. The road will have to build bridges of reinforced concrete to cross six large rivers and streams. These are the Adige, Progno, Tramigna, Alpone, Gua and Retrone. In addition a bridge will have to be built of the same material and strength to cross the Milan-Venice railway line. Fourteen small streams will have to be spanned and over 200 concrete culverts will have to be installed under the roadway. John E. Holler, U. S. Consul at Venice, reports that the total construction cost as outlined in the plans calls for an outlay of lire 63,243,675 ($3,328,514). The upkeep costs of the completed roadway have been figured at lire 4,459,740 ($234,716) annually, including not only repairs, but administration, as well as interest on the investment made.



Typical Chart Showing Peak Hour Traffic in 1926, Estimated Peak Hour Traffic of 1940, and Annual Maintenance Costs

Pavement Markings and Traffic Control An Interesting Discussion

The Problems on Intercity State Highways

By W. H. SHARP

Engineer of Repairs, Connecticut State Highway Department

DUE to the increase of volume of all classes of motor vehicle on our highways and the probabilities of still larger increases for the future, this subject is very interesting and vital and requires the earnest thought and study of all highway engineers as to its proper solution and standardization.

It is not my purpose to discuss, either pavement markings, or traffic control, insofar as it affects the cities, or congested areas in the larger towns, as these present their own particular problems, but to confine the discussion to the intercity state highways.

Pavement Markings.—Pavement markings play a very important part in the control of traffic on the intercity state roads. These traffic lines should only be placed on curves where the sight line is less than 500 ft. at all times and on hills where approaching traffic cannot be seen.

Such lines should be extended far enough on the tangent each side of the curve, or the crest of a hill, so that traffic will have ample opportunity to observe the line before reaching the point of danger.

In placing of the traffic line on curves, this line should not necessarily be placed in the exact center with relation to the edges of the pavement.

Each curve, which is to be marked with traffic line, should be carefully studied and several trials made with motor vehicle at varying speeds to determine the proper location on the pavement for the line.

This location varies with the sharpness, or degree of curve, as the traffic which follows the outside of the curve needs more pavement room to negotiate the curve.

In my opinion, the continuous traffic line defeats the real purpose for which it is intended. I have observed that where there is a continuous traffic line, the larger percentage of the motorists pay little or not attention to it, because when they come up behind slow-moving traffic they must cross the line to go ahead of the slow traffic. On dangerous curves, or hills, where the opposing traffic cannot be seen, these lines have little or no value.

The theory of the continuous traffic line should be that traffic should not cross said line, as these lines are placed in locations where any passing is dangerous.

There is considerable discussion as to the advisability of placing traffic lines on highways of more than two-lane capacity from the standpoint of safety and providing control conditions under which the highway may be used to its full traffic capacity. These lines may be crossed on necessity, but at the responsibility of the driver crossing the line.

If such traffic lines are adopted, they should be of a distinctive form so as not to confuse the motorist with the continuous traffic line, which is placed at dangerous points and which should not be crossed at any time.

If on the curve, or hill, where the traffic line is placed, there is an intersecting or cross road, there should be a break of sufficient length in the line to allow traffic to turn into the intersecting or cross road without crossing the traffic line.

From experiments and observation, the traffic line should be 6 in. in width, as a line of smaller dimensions is not readily seen, and white paint should be used, due to its high visibility.

Warning Signs.—The most progressive step taken for traffic control, by the use of signs, was the standardization of all warning and directional signs as adopted by the American Association of State Highway Officials, in conjunction with the Bureau of Public Roads as set forth in their manual and specifications issued in 1927.

Before such standardization was adopted, each state and each town in the state had its own design of sign, carrying various wordings and various symbols to cover the same objective, as well as various color schemes.

A sign to be effective must have a clear meaning and be easily read so as to tell quickly the message it is intended to convey. If a driver has to stop to read a sign, decipher it, and understand it, he will delay traffic.

The location on the highway of the various warning signs is very important. If it is a sign that requires immediate obedience, it should be placed where that obedience is to be given. If it is a sign that requires caution at some future place, it should be so located to give proper warning. The layouts, as given in the American State Highway Officials' manual, should be used as a guide, rather than a certainty, as each point to be signed must be studied for its local characteristics.

These signs should be so placed that they will be of value, both day and night, and also placed in such positions that they do not interfere with the maintenance of the pavement and shoulders, or snow removal.

It is our custom to place the signs so that the center of the sign is 3 ft. above the pavement, which brings the sign within headlight range for night driving and is also very clear for day driving.

Care should be taken that the proper sign should be placed at the proper location, also not to over sign, as too many signs are as bad as not any.

Illuminated Signs.—Illuminated signs should only be used where extra precaution is needed, and these signs should be of the amber or white color, instead of red, as the writer is of the firm belief that red reflecting signs should only be used where an absolute stop is necessary.

In Connecticut we have had excellent results in using the reflecting lens, incorporating these in the standard signs. As an illustration, at an important cross road, we have used the standard "Cross Road" signs, preceded by a "Slow" sign on all four corners, in which signs are incorporated the reflecting lens. At extremely sharp curves, or decided change of line of road, we are using the yellow sign with the plain black arrow, in which has been incorporated the illuminating lens, using these signs in place of red, or amber reflecting signals. This type of sign not only warns the motorist, but gives him the direction in which the highway turns at that particular location.

Directional Signs.—This also is a very important item of traffic control, as with proper directional signs placed in proper locations, they will aid the motorist to continue on his way without trouble. These directional signs should also be placed so as to be of full value for night driving, as well as for day driving.

Care should be used so as not to have too many directional signs at one location, and these signs should be readable so that the motorist will not have to stop to read, thereby causing a traffic hazard.

In general, our policy is to have not over three directional signs on a post; the top sign directing to the next city, or large town beyond the state border through which that particular route

goes; the next designates the next large city in the state, and the third sign the next town beyond. As an illustration, U. S. Route No. 5 starts at New Haven, going north through Massachusetts and Vermont to Canada. At New Haven the top sign will read Springfield, which is the next city beyond the state border; the second sign will read Hartford, as the next large city in the state on that route, and the third sign will read North Haven as the next town. After reaching North Haven, the Wallingford sign is picked up as the next town to North Haven, etc.

It is very important that all the signs should be well maintained. If the sign is to mean anything for the traffic, that sign should be maintained in the very best condition, not simply for the visibility and readability, but also for the psychology of impressing upon the motorist that the sign is placed for a purpose.

Automatic Signals.—On the subject of automatic signals, there appears to be a very wide difference of opinion as to the value of such signals.

In the writer's opinion, an automatic signal on intercity state highways should only be used in very extreme cases, as the use of such signals has a tendency to impede traffic, rather than expedite it; and where such signals have been used, the writer has observed that the traveling public pay little or no attention to it, in which case a very serious traffic hazard is created.

The only place on the intercity roads where an automatic signal should be used, is at a cross road, where traffic in all directions is approximately equal.

I will quote from the report of the Committee on Highway Traffic Analysis, in their proceedings of 1926:

"In order to facilitate the safe movement of traffic, regulations become necessary at congestion or danger point. These regulations in many cases take the form of an automatic signal, or similar device which governs the flow of traffic. These devices have increased in number and variety in the past few years.

"Some types of these signals, however, by either location, or operation, are defeating the end for which they are installed."

It would seem that in most cases, the control of traffic may be governed at so-called danger points by the adoption of the boulevard system, giving the main, or heavily trafficked roads the right of way and causing all traffic entering into this highway to come to a full stop and then proceed.

Other serious problems for traffic control are these: Obstructions such as pedestals in the paved highway carrying blinker signals, extreme sharp curves, bottle necks, sight lines at intersecting or cross roads and slow drivers.

It is not necessary to enter into any discussion on the question of the above-mentioned obstructions, as they have been very thoroughly discussed and published in the papers and magazines.

Re-routing Traffic.—There is also another important item in traffic control; that is, the re-routing of traffic around cities and larger towns.

Again I will quote from the proceedings of the National Highway Research Board:

"Within villages and cities through which a highway passes, the local parking of vehicles, operation of trolley lines, narrow or inadequately improved streets and construction, maintenance and police control of the highway route are under independent jurisdiction. Local vehicle and pedestrian traffic add to the difficulty of free movement of through traffic.

"It is a fallacy to believe that the benefit which accrues to a community from routing through traffic through the congested business section is at all commensurate with the cost of constructing and maintaining an adequate right-of-way, the danger and inconvenience to local vehicle and pedestrian traffic and the loss of local business.

"The loss of time and inconvenience caused to through traffic by its necessary passing through congested areas far exceeds any local convenience or benefit."

Acknowledgment.—The foregoing is a paper presented at the 5th annual convention Association of Highway Officials of the North Atlantic States.

Effect of Road Conditions on Vehicle Operating Costs

Relative Cost of Operation on Various Classes of Highways

It is believed that the effect of road condition upon vehicle operating costs may be estimated by the correct interpretation of a mass of research data that has appeared in recent years.

General Assumptions.—The relative cost estimates below were accordingly prepared in that way and the several assumptions in the analysis are as follows:

1. In order that seasonal variation in road condition may be taken into account, it was assumed that an automobile is operated regularly throughout the year, traveling at a speed of 30 to 40 miles an hour, and that the schedule (but not the speed) is maintained regardless of the condition of the roads so long as operation is possible. That is, the vehicle makes regular daily or weekly trips or some other fairly regular trip schedule, and does not avoid the days when the roads are not at their best.

2. The relative rate of tire wear is assumed to be 1.00 for high type roads, 2.12 for intermediate types and 2.90 for low types. This is based on tire wear researches.

3. The maintenance cost of the vehicle is assumed to vary in accordance with the work done by the motor in various kinds of service, measured by the rate at which the motor delivers power and uses fuel. This presupposes that the maintenance of the vehicle is due entirely to the wearing of parts, which is a conservative view to take, since other factors add to the effect of mechanical deterioration, especially when the vehicle is operated on low type roads.

4. Depreciation in the value of the used vehicle is due in part to mechanical deterioration and in part to obsolescence. It is assumed that one-half of the depreciation is chargeable to mechanical deterioration and one-half to obsolescence. The portion that is due to mechanical deterioration is assumed to vary with the work done by the motor as measured by fuel consumption. This view neglects the effect of road condition on the deterioration of the body of the vehicle.

5. From all of the accessible records of tractive resistance of automobiles the average tractive resistance for year-around operation at a speed of about 35 miles an hour was estimated for the three classes of roads as follows:

	lb. per ton
High types (pavements of all kinds in average good condition)	70
Intermediate types (gravel, macadam and bituminous treated surfaces)	110
Low types (natural soil roads and light gravel or sand-clay surfaces)	160

6. With these values of tractive resistance the average relative gasoline consumption was determined from reported engine tests and actual measurements on the road. The following results were obtained:

High types.....1.00 = basic rate
Intermediate types .....1.20 of basic rate
Low types .....1.47 of basic rate

The above figures signify that, as the average throughout the year, if a vehicle will travel 15 miles on a high type road per gallon of gasoline, it will take 1.2 gal. of gasoline to travel 15 miles on an intermediate type, and 1.47 gal. to travel 15 miles on a low type. Of course there are times when there is little or no difference in the mileage per gallon on the several types of roads but a comparison of the nature desired must be based on year around conditions.

Effect of Road Conditions.—The effect of these several variables upon cost of operation is most readily presented in the form given in Table I, in which factors are used to indicate the relative cost of each item of operation on three general classes of road. If the

Table I.—Effect of Road Condition on Various Items of Operating Cost

Item of cost	Sum expended for item when using high type roads	Sum required for equal mileage on intermediate type roads	Sum required for equal mileage on low type roads
Gasoline	$1.00	$1.20	$1.47
Oil	1.00	1.00	1.00
Tires and tubes	1.00	2.22	2.90
Maintenance	1.00	1.20	1.47
Depreciation	1.00	1.10	1.24
License	1.00	1.00	1.00
Garage	1.00	1.00	1.00
Interest	1.00	1.00	1.00
Insurance	1.00	1.00	1.00

cost of any item is known for one type of road, the cost for either of the other types may be calculated by the use of the appropriate factor from Table I. Obviously some items of operating cost are not directly influenced by road conditions. For convenience, the high type is used as the basis of comparison.

Average Cost of Automobile Operation.—In attempting to present a figure representing the "average cost of automobile operation," one is confronted with the fact that no specific automobile is an "average" automobile, although some classes are near the average in cost of operation. What is desired is the figure obtained by dividing the total cost of operating all cars during some period, say one year, by the total mileage operated for the period. No such figure is available, but if the costs tabulated in Table II are truly representative of the costs of the respective groups, a general average may be obtained by taking account of the proportion of each group in the total registration of automobiles. The result is given in Table III.

Since the automobiles, upon which the costs reports were received, were operated on all sorts of roads, the general average given in Table III probably represents the cost of operation on intermediate type roads more nearly than it does the cost on either high type or low type roads, and it is so considered. Whether this is true or not is relatively unimportant in the analysis that follows, as will be apparent from a casual examination of the tables. By applying the factors of Table I to the cost figures of Table III there is obtained a close approximation to the *relative* cost of operating an imaginary "average" automobile on the three types of roads. These costs are given in Table IV.

From the data of Table IV it is possible to estimate how the average figures of Table II would be affected by road conditions and Table V has been prepared to bring out this comparison.

One measure of the value of road improvement is the saving in vehicle operating costs effected. This may be determined from Table V, but for convenience of reference is tabulated in Table VI.

Table III.—Cost of Operation of an Imaginary "Average" Automobile*

(Annual mileage of 11,000)

Item of Cost	Cents per mile
Gasoline	1.31
Oil	0.22
Tires and tubes	0.64
Maintenance	1.72
Depreciation	1.39
License	0.14
Garage at $4 per month	0.44
Interest at 6 per cent	0.36
Insurance (fire, theft, tornado)	0.21
Total cents per mile	6.43

*By reference to Table II it will be seen that this is about the same as the cost for the "medium four" group.

Table IV.—Relative cost of operating an imaginary "Average" Automobile on Various Classes of Roads

Item of cost	Approximate relative cost of operation in cents per mile: High type roads	Intermediate type roads	Low type roads
Gasoline	1.09	1.31	1.61
Oil	0.22	0.22	0.22
Tires and tubes	0.29	0.64	0.84
Maintenance	1.43	1.72	2.11
Depreciation	1.26	1.39	1.57
License	0.14	0.14	0.14
Garage at $4 per month	0.44	0.44	0.44
Interest at 6 per cent	0.36	0.36	0.36
Insurance	0.21	0.21	0.21
Total cost	5.44	6.43	7.50
Relative cost	1.00	1.18	1.38

Table V.—Estimated Average Cost of Automobile Operation on Various Classes of Roads

(Annual mileage of 11,000)

Class of automobile (see Table II)	Cost of operation in cents per mile: High type roads	Intermediate type roads	Low type roads
"Light four"	5.10	6.02	7.03
"Medium four"	5.44	6.42	7.50
"Heavy four"	6.10	7.20	8.40
"Light six"	6.25	7.38	8.62
"Medium six"	7.12	8.40	9.80
"Heavy six"	8.00	9.45	11.00

Table VI.—Estimated Average Saving in Automobile Operating Costs Due to Road Improvement

(Annual mileage of 11,000)

Class of automobile (See Table II)	Savings in cents per mile: Low type changed to intermediate type	Intermediate type changed to high type	Low type changed to high type
"Light four"	1.01	0.92	1.93
"Medium four"	1.08	0.98	2.06
"Heavy four"	1.20	1.10	2.30
"Light six"	1.24	1.13	2.37
"Medium six"	1.40	1.28	2.68
"Heavy six"	1.55	1.45	3.00
Composite "average" automobile	1.07	0.99	2.06

Summary.—The foregoing analysis of the effect of road improvement upon automobile operating costs is presented as the best that seems possible with the data now available. Admittedly it is an estimate, but the utmost care has been exercised to obtain corroborative evidence and much fragmentary information has been unearthed to indicate that the figures presented are conservative and may be used for any purpose not requiring a high degree of exactness. Moreover, they emphasize the fact that road improvement of the right kind is in reality an investment that pays good dividends, and that is easily seen to be true even though the relative costs presented herein be discounted heavily.

Acknowledgment.—The foregoing is taken from Bulletin 91, written by T. R. Agg and H. S. Carter and issued recently by the Engineering Experiment Station of Iowa State College.

Table II.—Average Cost of Automobile Operation

Based on detailed cost records covering about 800 automobiles operated in various parts of the United States and an average of 11,000 miles per year. The reports were largely from fleet operators who purchase supplies at wholesale and the items of gasoline and tires have been converted to retail price basis.

Type of car	Light 4[2] Average		Medium 4[3] Average		Heavy 4[4] Average		Light 6[5] Average		Medium 6[6] Average		Heavy 6[7] Average	
Gross wt., tons (Approx.)	0.86		1.08		1.4		1.41		1.66		1.86	
Items[1]	Dollars per year	Cents per mile	Dollars per year	Cents per mile	Dollars per year	Cents per mile	Dollars per year	Cents per mile	Dollars per year	Cents per mile	Dollars per year	Cents per mile
1. Gasoline at 20 cents per gal.	147.40	1.34	125.40	1.14	144.10	1.31	149.60	1.36	167.20	1.52	157.30	1.42
2. Oil	27.50	.25	18.70	.17	17.60	.16	19.80	.18	22.00	.20	18.70	.17
3. Tires and tubes	66.00	.60	71.50	.65	77.00	.70	82.50	.75	88.00	.80	99.00	.90
4. Maintenance	170.50	1.55	210.10	1.90	227.70	2.06	214.50	1.95	236.50	2.14	278.30	2.53
5. Depreciation	137.50	1.25	154.00	1.40	172.70	1.57	192.50	1.74	229.90	2.09	282.70	2.57
6. License	12.00	.11	15.00	.14	22.00	.20	22.00	.20	26.00	.24	30.00	.27
7. Garage at $4 per month	48.00	.44	48.00	.44	48.00	.44	48.00	.44	48.00	.44	48.00	.44
8. Interest at 6 per cent	30.00	.27	42.00	.38	60.00	.55	60.00	.55	78.00	.71	95.70	.87
9. Insurance (fire, theft, tornado, liability)	23.00	.21	22.00	.20	23.00	.21	23.00	.21	28.00	.26	30.00	.28
Total	661.90	6.02	706.70	6.42	792.10	7.20	811.90	7.38	923.60	8.40	1,039.70	9.45
Annual mileage		11,000		11,000		11,000		11,000		11,000		11,000
Average miles per gallon gas		14.95		17.53		15.29		14.68		13.19		14.02

[1] 1. From reported costs reduced to uniform price per gallon.
2. Average reported.
3. Based on average retail prices of tires.
4 and 5. Reported for vehicles that had been operated for a period and then sold.
[2] Light 4—Fords, all types.
[3] Medium 4's—Chevrolet, Star, Overland.
[4] Heavy 4's—Dodge, Nash, Maxwell, Chrysler, Oldsmobile, Hupmobile.
[5] Light 6's—Essex, Chrysler, Oldsmobile, Studebaker, Oakland.
[6] Medium 6's—Chrysler, Buick, Jewett, Studebaker, Nash, Chandler.
[7] Heavy 6's—Buick, Studebaker, Hudson, Paige, Reo.

The Design of Concrete Paving Mixtures

Method for Determining Proportions of Each Material

By E. R. KENDALL
Assistant Director, Michigan State Highway Laboratory

TO properly design, from the standpoint of the engineer, knowledge is required of how to produce certain results in a specified length of time, at the least cost, using the materials that are available.

At the beginning of the 1928 construction season, it was the intention of the Michigan State Highway Department to determine the proportions by weight of the ingredients that enter into the composition of concrete paving mixtures, in order to obtain the maximum strength. The cement content was to be kept constant, using six sacks of cement per cubic yard of concrete. The aggregates used were to be the same as before; that is, specification sand and gravel or crushed stone, while the quantity of mixing water was to be such as to give a slump of about 1 in.

In treating this subject, an attempt will be made to show the interrelationship of the different ingredients used in concrete, and then to describe the methods by which the proportion of each material is determined.

Interrelationship of Ingredients.—To determine the influence of the several ingredients upon each other, it would appear logical to study: first, the combination of the water and cement in forming cement paste, second, the addition of sand to the cement paste, forming mortar, and finally, the introduction of coarse aggregate to the mortar to give concrete.

It is evident that the strength of concrete depends upon the binding qualities of the cement paste, since the aggregates themselves have no binding value. With a given cement, it is probable that the strength would be at a maximum if only enough water were used to combine chemically with the cement.

Dry cement contains about 50 per cent air voids. One can conceive that the addition of water to the cement up to a certain point might fill a portion of the voids without appreciably changing the volume of the resulting paste. Beyond that point, the addition of water increases the volume of the paste, and dilutes the mixture. This dilution of the cement paste would reduce the binding power, with a resulting decrease in the strength. Therefore, the ratio of the quantity of cement used to the resultant voids would be a measure of the strength of the binding material.

Ratio of Cement to Voids the Key.—As one studies the various methods of proportioning, there is brought home the very significant fact that all of the methods which give satisfactory results are based on the same fundamental principle; namely, that with a given cement, the ratio of cement to the voids would constitute a yard stick for measuring the strength. If the voids in the cement paste are entirely filled with water, the case in question becomes a direct application of the water-cement ratio theory.

The chief reason for adding sand to the cement paste is to reduce the cost of the mortar. It would appear that the most economical thing to do would be to add sand up to the point where the voids in the sand were filled with the cement paste. Due to the inherent characteristics of different kinds of sands and cements, this cannot be done without creating voids, the magnitude of which is different for each kind of sand and cement, and for each ratio of sand to cement. These voids have a dilution effect on the cement paste, with a consequent reduction in possible strength. Therefore, for a given quantity of cement, the amount of sand to be used should be such that the least possible voids will be obtained in the mortar.

It is evident that, within limits determined by the workability of the mix, the addition of coarse aggregate to the mortar increases the volume, thus reducing the cost of the concrete. The maximum strength with a given cement content would be obtained if the mortar just filled the voids in the coarse aggregate. This, however, for pavement work results in a mix that is too harsh. An excess of mortar must be provided in order to make proper finishing possible. Therefore, to make a workable mix, the gravel particles should be distributed more or less like plums in a pudding. If the cement content in the mortar is kept constant, the addition of coarse aggregate to the mortar will not affect the strength, because the strength of the mortar is the strength of the concrete.

Determining Percentage of Coarse Aggregate.—The excess of mortar that is required in order to insure workability has been determined by actual trial, and we have decided that, after the voids in the coarse aggregate have been filled, there should be an excess of mortar equal to about two-thirds of the voids in the coarse aggregate. The percentage of the coarse aggregate in the concrete was determined by the workability of the mix, by making up trial batches. We decided that the ratio of the absolute volume of the coarse aggregate in a unit volume of concrete (b) to the percentage of solids in a unit volume of coarse aggregate (b_o) should be kept constant, with a value of 0.775. This may be represented by the equation: $b/b_o = 0.775$. The absolute volume of the coarse aggregate per unit volume of coarse aggregate (b_o) may be easily determined by dividing its weight per cubic foot, in a loose, surface-dry condition, by its specific gravity and by the weight per cubic foot of water; that is, (b_o = Weight per cubic foot divided by Spec. Gravity $\times$ 62.4.)

Therefore, for a given weight per cubic foot of coarse aggregate, the mortar per unit volume of concrete may be determined by subtracting the absolute volume of the coarse aggregate in a unit volume of concrete from that unit volume of concrete. This may be expressed as ($m = 1\text{-}b$), where m is the volume of the mortar per unit volume of concrete, and b is the absolute volume of the coarse aggregate per unit volume of concrete. The absolute volume of the coarse aggregate per unit volume of concrete (b) may be determined from the equation $b/b_o = 0.775$.

From the foregoing, it is evident: first, that the strength of the concrete depends upon the binding material which may be measured by the ratio of the cement to the voids, the voids being air and water; second, that by adding the sand to cheapen the mix, voids are created which have a direct bearing on the strength of the resulting mortar; and third, that the gravel is added as a further diluent, but the maximum amount that may be added depends upon the workability, which, if the cement content in the mortar is kept constant, does not affect the voids in the concrete, and consequently the strength.

Determination of Actual Proportions.—To determine the actual proportions, by weight, of the ingredients used in concrete, we follow Talbot and Richart's method (more commonly known as the mortar void method), which appears to be highly adaptable on jobs where weight proportioning of materials is used. This method is described in Illinois Engineering Experiment Station Bulletin Number 137. Up to this time we have applied this theory to our requirements in rather a restricted manner, and have found it possible to develop a laboratory procedure which renders the application simple in the field, but we wish to give full credit to Messrs. Talbot and Richart for this method of design.

In order to understand the mortar void method of design, it is necessary to have a clear conception of the term "absolute volume." Visualize 1 cu. ft. of solid steel, weighing—say 490 lb. One cubic foot, then, is the absolute volume of 490 lb. of steel. Now imagine a similar block of steel, which, instead of being solid, is honeycombed with numerous air pockets. It would be found to weigh—say 245 lb. The apparent volume is 1 cu. ft., but the absolute volume is only five-tenths of a cubic foot, because in reality there is only 50 per cent as much steel in this specimen. In other words, if this latter specimen were melted down into a solid mass, it would occupy only five-tenths of a cubic foot. In a like manner, the apparent volume of the concrete making materials is quite different from their respective absolute volumes, except, of course, in the case of water. For instance, a cubic foot of gravel has about 40 per cent voids, but only has an absolute volume of six-tenths of a cubic foot.

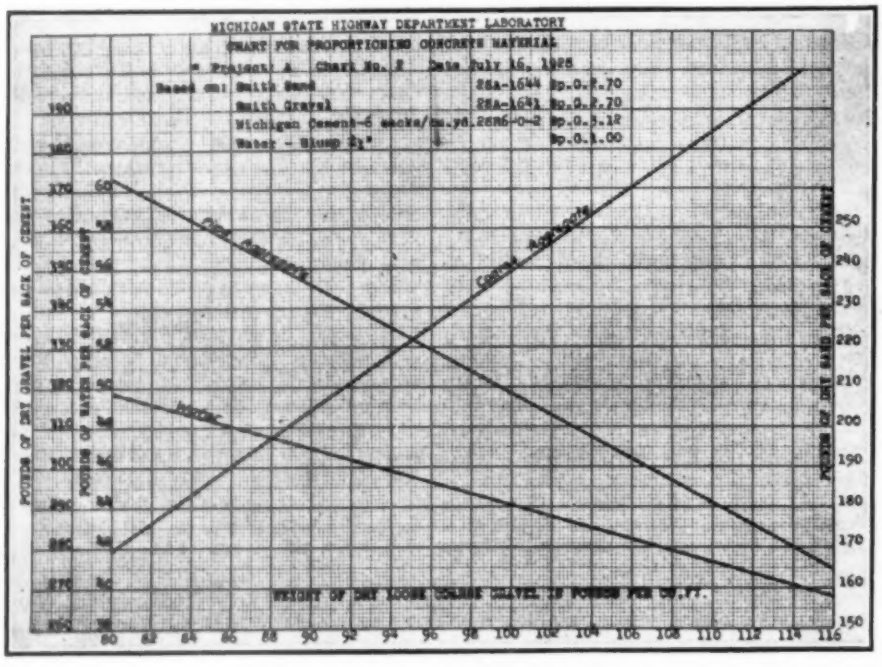


Chart for Proportioning Concrete Material

The mortar void characteristics of the particular kind of sand and cement used are obtained by mixing various proportions of cement, water and sand, and determining the resultant percentage of voids. It may seem like a rather laborious task to determine the percentage of the voids in the mortar with varying proportions of cement, water and sand, but in reality it is quite simple. Small batches are made up and tamped in the usual manner in small metal cylinders of known volume. The voids for each proportion, being the space occupied by air and water, is simply the difference between the volume of the batch and the absolute volume of the cement and sand.

Laboratory Procedure. — The actual laboratory procedure consists in determining the volume of batches of mortar of varying ratios of sand to cement and varying consistencies. The proportions of sand to cement are such that the ratios of the absolute volume of sand to the absolute volume of cement are 1.5, 2, 2.5, and 3. With a given ratio of sand to cement, just enough water is added to give a mortar of a dry consistency. Then successive increments of water are added until a mortar of practically a liquid consistency is obtained and the volume of the batch for each consistency is determined. We find the weight of the mortar is a 2 in. x 4 in. brass cylinder whose exact volume is known. The volume of the batch is equal to the product of the volume of the cylinder and the total weight of the mortar in the batch, divided by the weight of the mortar in the cylinder.

From the mortar void characteristics it has been found that, for a given proportion of sand to cement, a definite amount of water will give the densest mortar or the least voids. The addition of more water, or the use of less water, will only increase the voids. The amount of water used to give the densest mortar is called the basic water content. The basic water content does not give a plastic mix, but we find that with the coarse aggregates commonly employed, the water necessary to give the required workability is about twenty per cent more than the basic water content. This is expressed as a relative water content of 1.2.

The actual proportion, by weight, of water will depend upon the relative proportions of sand to cement, in addition to their individual characteristics. To obtain the maximum strength for a given proportion of sand to cement, the water required would be the amount that would result in the least voids in the mortar. As stated before, it is impossible to pour pavement concrete with a mortar of this consistency, so that the water used is about 20 per cent more than the basic water content. Consequently, as soon as the ratio of sand to cement is known, the amount of water can be easily computed from the basic water content for that particular proportion of sand to cement.

In order to estimate this ratio, voids are determined in mortar which is made up with a relative water content of 1.2, using varying proportions of sand and cement. From these data a curve is drawn, showing the relationship between the voids in the mortar and various proportions of sand and cement. Mathematically, this curve may be represented by the equation: $(Vm = f\ (am/cm)$, which indicates that the voids in the mortar (Vm) are some function of the ratio of the absolute volumes of the sand (am) to the cement (cm). This curve, or equation, constitutes one of the fundamental relations of the mortar void theory of design. The other fundamental relation is $(am + cm + Vm = 1)$ which means that a unit volume of mortar is made up of the sum of the absolute volumes of the sand (am) and cement (cm), plus the voids (Vm) (air and water).

We now have two independent equations and two variables; namely, the absolute volumes of the sand, and the voids in the mortar, since the absolute volume of the cement per unit volume of mortar can be readily determined. This may be computed by dividing the absolute volume of cement in a unit volume of concrete by the volume of the mortar per unit volume of concrete. The absolute volume of cement per unit volume of concrete is .108 cu. ft., since it is assumed that six sacks of cement will be used per cubic yard of concrete. As stated before, the volume of mortar per unit volume of concrete may be determined for a given weight per cubic foot. Solving these two equations simultaneously, the absolute volume of the sand to be used in the mortar may be determined.

We know the absolute volume of the cement, water and sand in a unit volume of mortar, because, not only is the cement content fixed, but after determining the absolute volume of the sand, the ratio of the cement to the sand can be obtained, and the amount of water computed. In order to determine their respective absolute volumes in a unit volume of concrete, each must be multiplied by the volume of mortar in a unit volume of concrete. This volume of mortar may be ascertained by subtracting the absolute volume of the coarse aggregate from the volume of the concrete. For a given weight per cubic foot of coarse aggregate, we now know the absolute volume of the ce-

ment, water, sand and coarse aggregate in a unit volume of concrete.

In order to determine the proportions by weight of the ingredients that enter into the composition of concrete, the absolute volumes of the cement, water, sand and coarse aggregate should each be multiplied by the weight of the unit volume of solid material. The weight, in pounds, of a cubic foot of the solid material may be obtained by multiplying its specific gravity by the weight of a cubic foot of water (62.4 lb.). If the unit volume of concrete is taken as a cubic yard, and each of the weight proportions is divided by six, it will give the proportions by weight per sack of cement, since six sacks of cement are required per cubic yard of concrete.

On the basis of this reasoning, we believe that the weight proportions obtained will give the greatest strength possible, using six sacks of cement to a cubic yard of concrete, and maintaining the required workability. In a word, since the strength is proportional to the ratio of the cement to the voids and the cement content is constant, the only way the strength can be increased is to reduce the voids to a minimum.

However, we desire, in the present year, to design for a definite strength. Probably the strength of the modulus of rupture will be about 700 lb. per square inch, at 28 days. This will necessitate making a series of tests in the laboratory in order that we may obtain the constants in the strength equation, the constants depending, of course, on the tensile strength of cement used, time of mixing, temperature, age, curing conditions, etc.

Since the excess of mortar is kept nearly constant, as is also the cement content, an increase of the voids in the coarse aggregate would have a tendency to make the mortar leaner. In order that the use of six sacks of cement will yield only a cubic yard of concrete, the proportions of sand and water must be varied with the weight per cubic foot of the coarse aggregate, since this weight is a measure of the voids.

The proportions by weight of the cement, water, sand and coarse aggregate are determined for the various weights per cubic foot of the loose, surface-dry coarse aggregate, and these data are plotted on the chart similar to those now in use in the field.

The mortar void charts are made up in the Laboratory at Ann Arbor, using samples of the materials actually used in the various weight proportioning jobs throughout the State.

In order to set his batch weights, the engineer in the field is required merely to determine the weight per cubic foot of the loose, surface-dry coarse aggregate. With this information he can read from the charts the weight proportions of the water, sand and coarse aggregate per sack of cement. Of course, moisture determinations of sand and coarse aggregate are made in the field, the weight of the surface water found being deducted from the weight of the water shown on the chart, and the fine and coarse aggregate weight proportions taken from the chart being increased by the weight of their surface moisture.

In order to measure the strength attained by this design, 6 in. x 8 in. x 40 in. concrete beams are made. Three beams are made from a single batch of concrete for every half-mile of pavement, and at important intersections, in order to determine if the strength attained is sufficiently high to open the pavement to traffic. The method of making and breaking the beams conforms to the Pennsylvania State Highway Department standards. The moulds are merely filled with concrete, the sides spaded, and the top struck off with a straight edge. The beams are broken at 7, 14 and 28 days, respectively, two breaks being obtained from each beam. The machine for breaking the beams is of the ordinary cantilever type, the initial load applied being 50 lb., and the load is increased in increments of 50 lb. up to 250 lb., and then in increments of 10 lb. up to the breaking point. Intervals of five seconds are allowed to elapse between each application of the load. The modulus of rupture is obtained by making the proper substitution in the formula: $(m = w_s + k)$, where m is the modulus of rupture in pounds per square inch, w_s is the load in pounds applied to break the beams, and k in the constant of the machine.

In a discussion of this sort, it is rather difficult to present a working plan of this method of design, but if one actually goes through the process of the design step by step, he will find that it is not so difficult to grasp as he might suppose. The ideas presented by Talbot and Richart are a little different from those to which we have been ordinarily accustomed. Consequently some of the concepts are more or less elusive until they are checked by actual experience in working them out.

Acknowledgment.—The foregoing paper was presented at the 15th annual conference on highway engineering at the University of Michigan.

The Gas Tax and Contractors Equipment

A law providing for a tax of 2 ct. per gallon on gasoline went into effect in New York State on May 1. Certain provisions are made in the law which will permit refund for gasoline used in machinery. The April issue of The Low Bidder, the official publication of the New York State Highway Chapter of the Associated General Contractors of America, in discussing how the new law may affect contractors performing state work and using equipment powered by gasoline motors, states:

"It is generally felt that gasoline used in power shovels, conveyors, cranes, tractors, pavers, pumps, crushers and numerous other items of equipment should be exempted from taxation. From a brief review of the law, it appears that road rollers, powered by gasoline, are the only machines which are specially exempted.

"This assocation has asked for an official interpretation from the State Tax Commission, so that contractors can be advised exactly how this law will affect their operations. It is felt that road building machinery in general should be exempted, including trucks which are used for state work. If contractors' equipment is not found to be exempt, bidders should figure on the added cost involved.

"The average state contract, covering a concrete paving job will probably require the following items of equipment, and will require gasoline in the amount estimated herewith, viz.:

	Gal. Per Day
10 Trucks—20 gal. per day each	200
2 Shovels—60 gal. per day each	120
1 Pump	15
1 Paver	35
1 Crusher	20
1 Tractor	20
2 Compressors—30 gal. per day each	60
2 Rollers (large and small)	30
1 Finishing Machine (two if requested by engineer)	5
1 Motor Grader	15
1 Loader or Conveyor	20
Estimated daily consumption	540

"It will be readily seen that the tax of 2 ct. per gallon will mean a daily tax of $10.80 for each working day."

The 1930 Road Convention

A special feature of the 1930 convention and exposition of the American Road Builders Association which is to be held Jan. 11-18 at Atlantic City, N. J., will be the group meetings and round-table discussions. The subjects under consideration have been selected as the most important in the highway industry and include committee reports on the following:

Special Committees

Highway Finance; Lien Laws; Equipment; Legislation; Grade Crossings.

County Highway Officials' Division

Legislation; Finance; Organization; Administration; Regional Surveys and Plans; Design and Construction—General Design of Location, Grading and Drainage, Plans, Specifications and Construction of Untreated Surfaces, Plans, Specifications and Construction of Pavements; Maintenance—Shoulders and Drains, Untreated Surfaces, Surface Treatments, Pavement, Maintenance Equipment, Snow Removal, Signs and Guard Rail.

City Officials' Division

Organization, Administration and Finance—Assessing and Financing Pavements, Uniform Cost Accounting; Design and Construction—Pavement Wearing Surfaces, Street Railway Tracks and Paving, Contracts and Specifications, Pavement, Subgrades and Bases; Maintenance—Pavement Bases, Surfaces of All Types, Street Openings or Cuts, Street Cleaning, Resurfacing and Salvaging of Existing Surfaces, Unpaved Streets; Traffic—Causes of Accidents, Traffic Signals and Signs, Street Lighting, Weights and Loads, Traffic Zoning, Traffic Law Enforcement, Drivers' Permits; Municipal Airports—Runways, Passenger Terminals, Hangars.

Contractors

Prequalification of Bidders; Latest Developments in Construction Equipment; Construction Cost Records; Recent Development in Grading Operations; The Highway Contractor as an Airport Builder; Pavement Guarantees.

Railroad Grade Crossing Protection

A Review of Important Aspects of Problem

By ROBERT H. FORD
Assistant Chief Engineer, Chicago, Rock Island & Pacific Ry.

THE grade crossing problem has reached a stage in this country where its effective solution has become a challenge to the engineer and the economist. It is essentially one of engineering and finance, in which the politician has no place.

There are 236,283 railway grade crossings in the United States and in spite of the vast expenditures being annually made for grade crossing separations, it is a disquieting fact that highway grade crossings continue to increase at a faster rate than they are being eliminated; or in other words, we have developed no definite objectives. The matter is still in the experimental stage and as yet we do not know how to meet the problem.

Definite Classification of Grade Crossings.—In a recent notable address before the American Road Builders' Association, Engineer E. W. James of the Bureau of Public Roads recommended that a definite classification of grade crossings should be made, based upon the relative value of their elimination to the traveling public and a definite program for eliminating crossings of highest classification be adopted by each state and by each of the railways within the state.

Presumably Mr. James had in mind that by this means there would also be eliminated those crossings which either by reason of their unnecessary character or relative unimportance, grade separation could not be economically justified.

He further states that "if the program of elimination, based on a classification, is to be founded on economic saving to highway traffic, it is logical and fair that there be a liberal allotment of costs to the general public, as by such a plan, it would make possible the speeding up of the entire program of grade crossing elimination."

The Benefit Basis for Allocating Costs.—This is in effect an endorsement of the fundamental principle of allocating the cost of grade separations to the parties benefited in proportion to the benefits received so far as they can be shown, as a substitute for the unsound, unscientific and thoroughly uneconomical policy of arbitrary apportionments which have nothing to justify them except that it is convenient and easily understood by petty public officials and politicians, and as such, it has crept into many state regulations.

The benefit basis, so-called for allocation of cost, has received the unanimous recommendation of a special committee of prominent railway engineers under the chairmanship of Hadley Baldwin, Chief Engineer of the Cleveland, Cincinnati, Chicago & St. Louis Railway, which committee was appointed to study and report upon the application of Federal Aid funds for grade crossing elimination. This committee was selected geographically so as to be representative of the railroads in the United States and their conclusion is the more noteworthy because it comes as the result of an independent study by each of its members. In its report made Nov. 21, 1927, it states that "the costs should be apportioned on the basis of the respective benefits resulting to the railways and to vehicular traffic."

The same principle has been followed in an interesting study by Engineer M. L. Hutton of the Iowa State Highway Commission in connection with research work on cost apportionments.

These conclusions are also in accord with the finding of Committee No. IX—Grade Crossings, of the American Railway Engineering Association, who reported that the cost of grade elimination should be spread over those who are benefited by the elimination.

The late Judge John E. Dolman of the Missouri bar, after an exhaustive study of the arbitrary assessment basis, reached the conclusion that it was as inequitable as it was unfair and the fruitful cause of controversy and misunderstanding.

Apart from the lack of a coordinated plan, that would among other things permit classifying the 236,283 existing grade crossings as between those that are necessary and those that are not, comes the further opportunity to classify the crossings that should be separated from those where separation is not economically justified.

Arbitrary Methods of Cost Apportionment.—The greatest stumbling block, however, to any general program of grade separation or grade crossing reduction, is the arbitrary and unsound methods for cost apportionment, and while there are decided evidences of a better grasp on the situation in some states, it must be said that the reverse is the case in other states.

I have taken occasion to examine several of the latter cases and have found that almost without exception they can be traced to either personal or partisan motives on the part of individuals or to log-rolling methods of politicians. In both cases the projectors have little knowledge of the broader aspects of the situation.

It has been my observation that where the matter is centralized in the hands of competent men with technical training, and especially if fortified with a background of training with public service bodies, there is a greater assurance of success in the advancing of the entire problem than where the conditions are otherwise.

Reliance upon the laws of the horse-drawn vehicle age to force separations or by similar methods to compel arbitrary cost apportionments, will foredoom to failure any constructive effort for a solution of this problem. It is the fruitful source of irritation and misunderstanding between the affected interests because of its manifestly unfair and inapplicable provisions from the standpoint of modern requirements, irrespective of state laws or court decisions, which are frequently held as a threat or a club in an effort to force acquiescence.

Any basis which apportions the cost equally between the state and the affected railway on the theory that they are equally benefited, is wrong and will never lead to success in working out the problem because, and for the reasons heretofore stated, accruing benefits are not arrived at in this manner, and every engineer and economist knows it.

Ultimately I believe that general formulas in the nature of guiding principles will come into general use for this purpose. Until this has been accomplished, and as suggested by Mr. James, a sufficiently liberal portion of the cost must be assumed by the general public to make it well within the ability of the average railroad to participate in the state program.

A little reflection will indicate that the public interest is best served if where two separations are necessary, they can be secured on an apportionment of, say, 25 per cent to the railway than by holding out for a 50 per cent or greater division to the railway on one separation. Thus no separation is obtained until the matter can be fought out singly through court action because one of the parties believes that such a division is as unfair as it is unjust.

It has been my observation that in those states where the apportionment of cost is the more liberal, that the speediest and most satisfactory action by all paries is obtained, and I invite your attention to a study of the purely

financial returns in the development of improved roads that result from a policy of this character.

Accident Prevention at Grade Crossings.—The time has gone for considering grade crossings from a purely accident preventive standpoint. Accident prevention at grade crossings is of course important and necessary but its work is largely educational, and which by the way should not be left entirely to the railroads to undertake. Consistent and persistent education of the public, aided by suitable legislation, will operate to secure a great reduction by proper preventive and corrective methods, but however laudable its purpose and accomplishment it has little effect on the matter of convenience and necessity in speeding up traffic and the prompt dispatch of vehicular traffic over the highways, which is of special value and importance to the general public.

The Committee on Construction and Engineering of the Hoover National Conference on Street and Highway Safety, recommended:

"Before improving an important highway which has grade crossings or serious disadvantages, consideration should be given to the possible substitution of some parallel route free from such difficulties even if little traveled at present."

With grade crossings increasing at a faster rate than they are being separated or closed, it would seem that the time has come when the creation of additional grade crossings should be prohibited by appropriate state legislation except for relocations or where closings or combinations will result in a reduction of the number of local crossings. The time has also come when all necessary grade crossings should be protected for the same reason as for any other dangerous point on the public highways, and the cost apportioned to those benefited in proportion to the benefits received, the only exception being for switch and other tracks of a similar nature of where the traffic is so infrequent as to justify no action.

Kinds of Grade Crossing Protection.—A summarized comparison of the various protected crossings in the United States, with the form of protection as reported by the Interstate Commerce Commission, and corrected to date, is as follows:

Kind of Protection	
Gates	5,747
Watchmen	7,302
Signals	16,627
Fixed Signs	204,742
Total	234,418
Otherwise Unprotected	3,426
Grand total	237,844
Increase in 1928	1,561

It is to be noted that the number of crossings protected by gates or watchmen is decreasing, and those protected by signals is increasing.

Where applicable, the automatic signal, or "24-hour mechanical flagman" as it is popularly known, should be used. This is especially desirable in the interest of uniformity and safety. The automatic signal is steadily replacing manually operated gates and flagmen as the safest and most reliable form of protection.

Signal at Grade Crossings.—Grade crossing protection to be efficient and satisfactory requires that there be two signals at each crossing, namely, the home signal, which should be placed sufficiently close to the tracks to prevent pocketing of an automobile between the signal and the rails, and the distant or advance warning signal or sign, should be on the side of the road and in conformity with the regular practice of state highway authorities and placed a sufficient distance from the grade crossing to enable the auto driver to know of his approach to a railway grade crossing and prepared to stop on the flash of the signal warning lights or movement of the wigwag which give notice of the approach of a train.

Under usual conditions, these lights are regulated so as to start flashing 20 seconds before the train reaches the crossing. This is done through electrical contact between the advancing locomotive and the track circuits. For a train approaching at the rate of 60 miles per hour, this is rated at approximately 1,760 ft. along the track from the crossing.

Placing of Signal.—Irrespective of the claims which have been made to the contrary, the investigations of many of the railroads support the beilef that where practical, the home signal should be placed in the center of the improved highway, which should be widened sufficiently for the purpose, both on the approaches and at the crossing. Similar recommendations were made by the joint special committee of railway engineers collaborating with the engineers of the Illinois Commerce Commission, and this practice is being followed on all but the Federal Highway System.

The railway sawbuck sign with the words "RAILROAD CROSSING" is now standard on all railways in the United States and is erected on either side of the track at practically all grade crossings in the country. It may be noted here as a further evidence of the need of drastic revision of our highway laws, that twelve of the forty-eight states have various other kinds of legalized signs for grade crossings, very few of these states being in agreement with the sign required by the other state, and as usual, the regulations being evidently the product of uniformed persons.

The practice of black and white striping for protective devices is now almost universal and is recommended by the Grade Crossing Committee of the American Railway Engineering Association, who have also recommended that the number of tracks to be crossed shall also be suitably marked by a numeral on the standard sawbuck crossing sign.

The practice of paving marking by black and white stripes opposite the advance warning sign (or where the sign ought to be located) is not so universal but it should be; also the use of the black traffic line for dividing traffic, which should be carried up to the railroad crossing. This line is one of the best of the contributary safety measures at grade crossings and its use as such was endorsed by the Hoover National Conference on Street and Highway Safety.

It is indeed unfortunate that our highway and civic authorities do not or cannot find some means for cooperating with the railroads in the removal of all signs and other devices of an advertising character for the entire distance between the advance warning signs on both sides of the track. These billboards or signs, whatever be their nature, are one of the principal contributing causes of accidents at grade crossings, both because of their obstruction to the vision of the engineer on approaching trains and because of the distracting or confusing effect on the auto driver.

The determination of the crossings which can be adequately protected by automatic devices, either permanently or against the time when they may be relocated, combined or separated, calls for an impartial investigation by competent authority, free from local influence or the restrictive effects of preconceived long distance rulings which too frequently are found to compel arbitrary requirements. Many of the crossings that are now urged for separation can be adequately protected by modern signaling and protective devices and in the light of the many urgent crossings where grade eliminations should be made, separations at such points are not economically justified.

Railroads Best Judge of Form of Protection.—In this connection, candor compels the statement that the attitude of some of our Federal and state authorities is too restrictive and leaves much to be desired. From the nature of the situation, the railroads are in a better position to judge of the best form of protection to their tracks because in the last analysis, they are required to assume the burden of the responsibility in cases of accident. Every railroad follows such matters through their organized safety and claim departments and it is not in keeping with good practice or conducive of cooperative advancement for the Federal Department of Highways or State Highway Commissions to arbitrarily insist upon the type, character and location of protection while at the same time assuming no responsibility either with respect to cost, maintenance or the results of their insistence in the event that an accident occurs.

It is to be hoped that the Federal De-

partment of Highways will recognize that at least insofar as they are concerned, that after all these are matters of local concern and policing and should have nothing to do with the administrative functions for which the department is so admirably equipped.

Mr. James, in his address previously referred to, recommends that the cost for installing protective devices should be shared between the states and the railways, and while no doubt he referred especially to the main state arteries, the same principle applies to all unprotected grade crossings. As in the case of grade separations, the greatest difficulty in this direction arises from a lack of centralized authority and an unwillingness on the part of many public officers and highway authorities to work with railroad authorities in protecting the public at grade crossings.

Again the old bogey of horse and wagon operation on the highways appears in the forefront, and it is to be regretted that there is not a more wholehearted cooperation between the highway authorities and the railroads in sharing in the relatively small expense that is involved in policing these crossings.

Use of Modern Automatic Device.—The average grade crossing can be protected and maintained by modern automatic devices at a relatively small expense, including the initial outlay for construction, which includes the widening of the pavement, in the same manner as is now being done at sharp curves and highway intersections. The effect on the driver is as much psychological as it is beneficial in other ways. In like manner the railroad crossing should be widened to meet the improved highway and the costs of construction and maintenance thereafter should then be apportioned on some mutually satisfactory basis.

What the Railways are Doing.—As indicated in this review of some of the more important aspects of the grade crossing problem, which is national in character and closely inter-related to our business, social and economic life, the American railways have attempted a collective approach to the subject.

They assigned to Committee IX—Grade Crossings, of the American Railway Engineering Association (which association also functions as the Engineering Section of the American Railway Association) its engineering and economic features and through their Safety Section the study of the safety and accident preventive features, while to the Claim Division has been assigned the study of relative values and the collection of statistics which become available through claim causes and similar contacts, public and otherwise.

All of these organizations are composed of specially trained railway men and in their name and in the name of President Aishton and his associates of the American Railway Association, I can assure the conference that the railways welcome wholeheartedly opportunity for conference and suggestion, recognizing meanwhile that as a vital public problem of national aspect, the approach to its solution is after all through the medium of education and cooperation, in which the engineer and his associate, the economist, should take a prominent place.

The work of such men on this question like every other public question, is of immeasurable value because they are trained in the ways of research, fact finding and analysis, and their services can be of great public benefit by sifting out essentials from non-essentials and in suitably developing and presenting pertinent facts, data and other information in a way that they can be readily recognized and be thus available for use by proper public authorities.

Acknowledgment.—The foregoing is an abstract of a paper presented at the 1929 Conference on Highway Engineering at the University of Michigan.

The 1930 Road Convention and Show to Be Held at Atlantic City

The 1930 convention and road show of the American Road Builders' Association will be held in Atlantic City Jan. 11-18.

This announcement was made on May 3 at the annual business session of the association by Frederic A. Reimer, consulting engineer of East Orange, N. J., the incoming president.

The president's dinner and installation of new officers followed a two-day meeting of all association committees, divisions and the directorate. Reimer succeeded R. Keith Compton, director of public works, Richmond, Va., who became a director.

James H. MacDonald, New Haven, Connecticut, continues his years of service as treasurer and Charles M. Upham, Washington, D. C., continues as secretary-director.

Other new directors are J. S. Helm, Standard Oil Company, New York, and Arthur W. Dean, chairman, State Highway Commission, Boston, Mass.

Charles E. Grubb, county engineer, Wilmington, Del., was today installed as head of the County Highway Officials' Division, succeeding T. J. Wasser, Jersey City, N. J.

Senators, representatives and high government officials joined with diplomatic representatives of many Pan-American countries at the dinner tonight. A majority of the United States were represented by road builders, engineers and others connected with the industry.

Atlantic City was chosen for the 1930 meeting after a long and vigorous fight on the part of Cleveland to have the road builders return there. Cleveland has entertained the past two gatherings, the most successful in the organization's history. St. Louis also was a spirited bidder for the meeting.

"The board of directors are of the opinion that it is advisable to hold the convention and exposition in different parts of the country from year to year," Upham declared. "We had that policy in mind when we left Chicago two years ago after meeting for five years there, and brought the 1926 show to Cleveland.

"That year's convention was so successful as to cause our return there last year, but a further change of location this year is deemed suited to the best interests of our entire association."

Upham predicted a greater attendance, not only of engineers and highway officials from the United States, but of Pan-American and European representatives at Atlantic City than has ever before gathered for a road show and convention. All Pan-American steamship lines are granting a 25 per cent reduction in fares for the convention, he said.

Twenty Pan-American countries and ten nations of the Old World were represented in the attendance last January at the Cleveland convention and show.

Contract Prices on California State Road Work

The accompanying table rearranged from the 6th biennial report of the Division of Highways of the Department of Public Works of California shows the weighted average contract prices on state highway work during the past 16 years.

Weighted Average Contract Prices from 1912 to 1928

	1912-16	1917-18	1919-20	1921-22	1923-24	1925-26	1927-28
Grading, per cu. yd.*	$0.49	$0.74	$1.01	$0.78	$0.74	$0.53	$0.54
Asphaltic Concrete,† per ton	6.49	8.52	9.07	7.98	7.75	5.80	4.89
Concrete,† per cu. yd	6.35	8.67	14.82	15.75	13.40	10.78**	10.56**
Sand, delivered, per ton	.56	.76	1.17	1.63	1.31	.....	.....
Broken stone and gravel, delivered, per ton	.78	.96	1.37	1.94	1.80	.....	.....
Cement, delivered, per bbl.	1.70	1.90	2.66	3.23	2.96	.....	.....
Concrete, exclusive of all materials, per cu. yd.	2.92	4.51	7.00	6.96	5.16	.....	.....

*Includes all classifications, except that of structure excavation and preparation of subgrade is not included in the averages for 1924 to 1928.
†Including all materials.
**Portland cement and concrete pavement, including all materials.

Fibrated Asphalt Planking Waterproofing Floor Construction on LaSalle St. Bridge, Chicago

Of late years a great deal of attention has been directed by engineers to some vital requirements in the construction of floors and of the waterproofing course, on both fixed and movable bridges and on the approaches to such structures.

In the specification of materials entering into the construction of the La Salle St. bridge, Chicago, and the approaches to it, considerable attention was devoted on the part of engineers to the requirements of this particular structure—first, as relating to the waterproofing, and second, relating to the wearing surface on the bridge itself.

The illustration, Fig. 1, is of the north approach to the bridge, and the picture shows a crew installing Servicised fibrated bituminous waterproofing planks directly over the waterproofing fabric itself. On the deck pictured, 14,000 sq. ft. of fibrated asphalt sheets, 24x36 in., were laid as a protection to the waterproofing. The waterproofing fabric was laid over the concrete, and while the asphalt was still in a plastic condition, the waterproofing fibrated asphalt planks were placed in position. The granite block paving for the bridge approach was laid immediately over the waterproofing protection course.

The preformed fibrated bituminous sheets provide a blanket of tough, resilient material over the waterproofing, which reinforces the waterproofing itself by increasing its thickness or body, and so protects it from direct damage. It is claimed that due to the fibrous nature, toughness, high tensile strength and the inherent waterproofing qualities of the protection course, the integrity of the waterproofing is maintained indefinitely, regardless of shock and vibration from traffic, the condition of the weather or the state of the temperature.

Its use prevents leaks through the structure, as the greater the pressure upon it, the tighter the waterproofing becomes. The material is sufficiently strong and tough so that it bears the usual loads without distortion.

The very quality of resiliency and toughness enables it to give and take the movements of the main structure. Such a waterproofing course has also some of the qualities of an expansion joint in that it is unaffected by extremes of temperature.

Figure 2 shows Servicised fibrated asphalt plank being installed on the south leaf of the La Salle St. bridge.

The outstanding feature of fibrated asphalt planking is its adaptability to any particular surfacing requirement. The composition of the material can be varied to meet the practical necessities in each case. Fibrated bridge flooring material is constructed of asphalt saturated felt and asbestos fibre for binding, and of asphalts thoroughly mixed with fine mineral matter for compressive strength, and for increasing the abrasive and wearing qualities.

To increase the tensile strength, mats of irregularly overlapping fibre are introduced and further resiliency is effected by inserting divided fibre between the spaces or mats of the linear fibre.

According to the manufacturer, when the material is finally incorporated by pressure, into a block-like structure, it is then a composition of extreme toughness, highly resistent to wear and at the same time, extremely resilient and accommodating itself easily to the expansion and contraction movements of the bridge structure.

It is easily laid, in fact just as easily handled as wood planking. There is no difficulty in using the material any time of the year in any climate and without especially trained labor.

Fig. 2—Servicised Fibrated Asphalt Planking Being Installed on the South Lift of the La Salle St. Bridge, Chicago

Highway Employes Study Methods

More than 300 engineers, maintenance superintendents, inspectors and other employes of the Pennsylvania Department of Highways, met at Harrisburg March 13-15 for a 3-day conference of instruction on construction and maintenance methods. Officials of the department in charge of various phases of activity officiated at meetings devoted to their own phase of the work.

Meetings were conducted by: W. A. Van Duzer, assistant chief engineer; P. M. Tebbs, assistant chief engineer; R. V. Warren, township engineer; C. C. Albright, office engineer in charge of locations; Thomas D. Frye, comptroller; C. A. Eichelberger, equipment engineer; H. S. Mattimore, engineer of tests, all of the headquarters staff, and the following division engineers: T. C. Frame, Franklin; J. S. Ritchey, Williamsport; S. W. Jackson, Clearfield; J. L. Herber, Pittsburgh; W. D. Meyers, Hollidaysburg; S. P. Longstreet, Harrisburg; D. C. Stackpole, Philadelphia, and C. H. Buckius, Scranton.

Fig. 1—Servicised Waterproofing Slabs Being Installed on the North Approach to the New La Salle St. Link Bridge, Chicago. Approximately 14,000 Sq. Ft. of 24x36 In. Fibrated Bituminous Planks Were Used, and the Granite Block Pavement Laid Immediately on This Cushion.

Highways—A Public Utility

The Highway Department as a Public Service Corporation

By C. H. BUCKINS
Division Engineer, Pennsylvania Highway Department

THE Pennsylvania Department of Highways is a gigantic business corporation, providing a transportation organization for motorists and other users of the highways on a state-wide system of 13,330 miles and state and state-aid highways. This mileage is larger than most of the large trunk line railways of the United States, and is the largest of the state highway systems of the country. Unlike a railroad system which provides complete transportation, the Pennsylvania Highway Department provides and maintains only the roadbed, the units of transportation or motor vehicles being supplied by the users of the highway who occupy the unique position in Pennsylvania of being sole stockholders of the corporation of the highway department The highway department is a mutual corporation. The users furnish the funds to operate by paying for the privilege of using the roadway and receive from the department dividends in the form of improved service and actual savings in operation costs which are tangible evidences of satisfactory management.

Charges for Services Rendered.—The terms "Motor License Fee" and "Gasoline Tax" are misnomers. Considered as "taxes," they become the object of attack. Let us consider these funds, not as taxes, but as charges paid for services rendered, in the same manner as we would pay for freight or passenger transportation to a railroad, trolley or omnibus corporation; local service and long distance calls to a telephone company; light, gas, and water service to a company engaged in those lines of business; premiums paid to insurance companies; rent paid for house and garage service or in fact money paid to any company or individual from whom you purchase a tangible object or a necessary service. In transactions of this kind we must pay a rate established by the companies or individuals in charge of the management, which, in the case of public service corporations must be approved by the controlling government agency, established by the legislature. By reason of the class of service rendered the highway department may properly be classified as a public service corporation.

How much is being paid to the highway department each year; how the money is being expended; the value received and how this affects the individual user of the highway, is worthy of consideration.

Motor Vehicles, Fees and Gas Tax.—In 1928, 1,428,514 passenger and 225,299 commercial vehicles were registered in Pennsylvania, from which $27,113,777.10 in motor license, driver's license and title fees, etc., were received. During the same period almost $24,000,000 were collected from gasoline tax of which approximately $4,000,000 or ½ cent per gallon was returned to the counties in which the tax was collected. This makes a total service charge of the motorist of $51,000,000 for 1928. Dividing the total number of passenger and commercial vehicles of 1,653,813 into this amount shows an average service charge for road use of slightly less than $31.00 per car.

What has been and is being accomplished with this money? Of the 13,330 miles on the highway system, approximately 8,830 have been improved, leaving 4,500 unimproved. Practically all of these improvements have been made since 1911 and 5,800 miles of it since January 1, 1919. Since 1925 construction of new highways has been going forward at the rate of approximately 500 miles per year. Sufficient money available through bond issues in 1925 permitted a large construction program, and as a result 780 miles were built that year.

The construction of 8,830 miles of road has increased property values and added to the health, wealth, comfort, convenience and happiness of our people. It has promoted trade between the farmer and the city merchant with resultant increase in prosperity of both. It has expanded the production and growth of the motor car industry and its accessories. Nevertheless, few analyze or realize the direct saving in operation of our vehicles.

Savings from Improved Roads.—Extensive studies and experiments were undertaken by the United States Bureau of Public Roads, several state highway departments and leading universities to determine the cost of operating motor vehicles and the savings which result in these costs in operating over an improved road as compared to an earth road. The results of this research showed that the approximate cost of operating the average passenger car was $0.10 per mile and the average truck $0.36 per mile. The traffic studies made in Pennsylvania by the United States Bureau of Public Roads shows the average improved road to carry more than 1,000 vehicles per day. Using a minimum of 1,000 per day, of which 900 are passenger cars, 100 are trucks we find the operating cost on a mile of highway is,

900 cars x0.10=$90.00 passenger cars
100 trks.x0.36=$36.00 trucks

$126.00

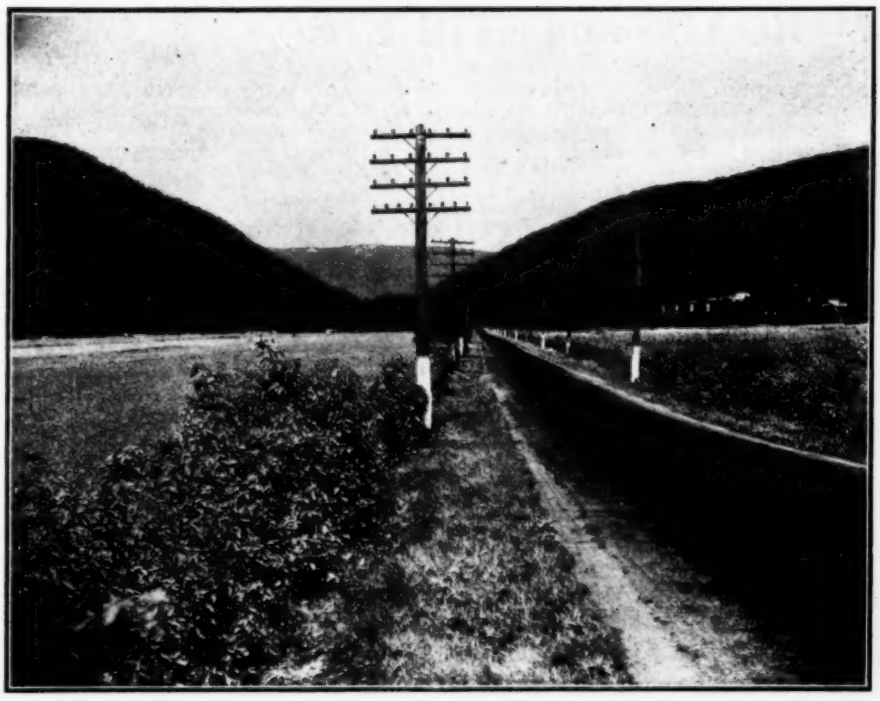
On a basis of 365 days per year this amounts to approximately $46,000.00 per year. These same studies and experiments showed very plainly that the saving in operation on an improved road was more than 25 per cent as against operating on an unimproved road. On this basis the saving per year to Pennsylvania motorists is 25 per cent of $46,000 or $11,500 for each mile of improved road. For the 8,830 miles of road now improved the saving at this time amounts to $101,545,000 per year. This saving to the motorist is a direct dividend return on the mutual principal.

In other words $51,000,000 were collected in 1928 from the motorist and

The Cost of This Pennsylvania Concrete Highway Was Paid by the Users

$101,000,000 were returned in saving in operation costs. In addition, the highway department has shortened the highway system by more than 210 miles through relocations which not only eliminated bad curves and grades but saved the motorists 210 miles of travel distance. Reducing this to saving in operating costs it amounts to another $10,000,000 per year. This is a direct saving in the same manner as you would not pay for riding on a train for a mileage which had been eliminated from the trip. Added to the gross annual saving of $101,545,000 in operating costs due to road improvement, the total gross annual saving is $111,545,000.

The Demand for Additional Improved Highways.—Next to the economic feature of operation must be considered the demand for additional improved highways. The automobiles purchased and owned by the motorist must have sufficient roadbed upon which to operate if they are to secure the full benefits for which they are paying a road service charge, and secure the full dividends promised upon rapid, safe and economical operation.



Improved Roads Are Now Bringing the Tourist Traffic and Trade to Picturesque Pennsylvania

On Jan. 1, 1919, a total of 394,000 vehicles were registered in the state of Pennsylvania. On Jan. 1, 1929, the total reached 1,654,000. This represents an increase of 320 per cent in the 10-year period. On Jan. 1, 1919, 3,030 miles of improved road were on the state system. On Jan. 1, 1929, this mileage had increased to 8,830 miles or an increase of 191 per cent. The same motorists or stockholders, therefore, by one expenditure, under private control increased the rolling stock 320 per cent but only permitted public expenditure of their moneys to furnish an increase of 191 per cent in roadbed.

In 1919, there were 130 cars for every mile of improved road. In 1929, this increased to 187 cars for every mile of improved road, representing an increase of 44 per cent in density of traffic in cars per mile. This increase has resulted in several notable conditions:

1. Dangerous driving.
2. Slow transportation.
3. Reduces market for motor cars, trucks, and accessories.

The first two results are very obvious to every motorist who must use our highways for business or pleasure, especially over week ends and holidays. The third result is not generally recognized even by individuals and firms engaged in the manufacture and sale of motor cars and motor products. In the entire United States there is approximately one car for every five persons. In states such as California and Kansas there is one car for every three persons. In Pennsylvania there is only one car for every seven persons. The only states who have fewer cars according to population than Pennsylvania are:

North Carolina	Kentucky
Montana	South Carolina
West Virginia	Arkansas
Virginia	Alabama
Louisiana	Georgia
Mississippi	Tennessee

Pennsylvania, the second wealthiest state in the United States, although fourth in total number of registration, is 36th in number of cars compared to population. We have the business; we have the desire; we have wealth but we do not have the roadbed upon which to operate with safety, comfort and convenience. The only answer is "More improved roads at the earliest possible date."

The Motoring Public Foots the Bill.—Considerable discussion as to the amount of money which Pennsylvania collects and expends upon its highway system, especially as it affects the motorist, has engrossed the public attention. Pennsylvania collects the entire bill from the motoring public. This policy is fundamentally sound. We would resent telephone, gas, water, transportation or light bills from companies if we did not use their products. In fact, today, we do pay a "Ready to serve" charge or tax to many public service corporations even though we may not have used their product or service during a certain period. Many other states spend as much or more than Pennsylvania. Gross amounts should not be taken as the basis of comparison, but amounts in comparison with population and wealth should be considered in accordance with figures compiled by the American Association of State Highway officials, the average expenditure for all states per capita is $6.47. In Pennsylvania it is $5.51 or 14 per cent less than the average. For each $100 of wealth the average is $0.23 as against $0.18 in Pennsylvania or 22 per cent less.

For many years Pennsylvania was not visited by tourists on account of our poor highway facilities. Due to the wonderful record of the past ten years, this obstacle has been overcome and the tourist business of Pennsylvania is now estimated in the hundred millions. Some of the most scenic portions of Pennsylvania are still undeveloped by reason of unimproved roads. If we are to hold our present touring trade and secure additional we must make these scenic wonders accessible by the immediate construction of new highways.

New Heavy Traffic Road Between Liverpool and Lancashire, England, to Be Constructed.—A new heavy traffic road is to be constructed between Liverpool and Lancashire, England. It is to be 25 miles long, with 80 ft. of total roadways, a center carriage-way of 40 ft. for fast traffic, bounded on each side by a grass verge, which separates it from two 20-ft. carriage ways for slow moving traffic, also, two footpaths each 10 ft. wide. The estimated cost of the present scheme is $13,112,746. It is to be of reinforced concrete and the work is to be carried out under the Unemployment (Relief Works) Act of 1920, and it is expected that it will find employment for over 2,000 men. The contracting firm is: Sir Lindsay Parkinson and Company, Ltd., Contractors, Borrow-in-Furness, Lancashire, England.

ROADS and STREETS

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The Gasoline Tax—Past, Present and Future

Ten years after the first two states adopted a gasoline tax every state in the Union will have followed the lead of those pioneers, Oregon and Colorado, for Massachusetts and New York have at last joined the procession and Illinois has passed a new gasoline tax law to take the place of the one that was held invalid about a year ago.

As this magazine has maintained from the start, the gasoline tax is not only one of the most equitable of taxes, but it supplies a steady flow of road funds. Moreover the flow bears some relation to the demand for improved highways.

In 1928 the gasoline tax totaled $305,200,000, at the rate of almost exactly 3 cts. a gallon. With three populous states to swell the "toll" during most of 1929 and with a substantial increase in the number of cars, it is probable that more than $325,000,000 will be collected in gasoline taxes during 1929, to which must be added the license taxes of about $330,000,000.

The average motor vehicle used about 500 gals. of gasoline during 1928, and if 16 miles per gallon were averaged, this means 8,000 miles per vehicle, or 160,000,000,000 car-miles for the year. Since about 8,000 passengers (including drivers) were killed, there was about one passenger killed per 20,000,000 car-miles. But if the cars averaged 1.5 persons per car, this means that one was killed for every 30,000,000 passenger-miles. By taking an occasional traffic census, it should be feasible to attain great accuracy in estimating the risk of travel by motor car. Railway statistics show that for American steam railways there is one passenger death per 371,036,824 revenue passenger-miles.

The next important step to be taken is the application of part of the gasoline tax to the improvement of certain thoroughfares through towns and cities. Five states have already begun to do this, and it is evident that others will soon follow their lead. Bottleneck streets and bumpy pavements will disappear rapidly once the policy is adopted of ignoring political boundary lines.

We have commented again and again upon the injustice of placing the entire burden of street improvement upon abutting property owners wherever the street is a thoroughfare of importance. Not only is it inequitable to do so, but the resistance of the property owners to an unjust tax burden often results in delaying street widening, or paving, or both, for a decade or more after it has become an economic necessity.

Another cent a gallon of "gas" would add only $5 a year to the tax paid by the average motorist, and if this added income were devoted to improving highways through towns and cities it would soon work wonders in relieving congestion.

The Department of Agriculture has recently estimated that only 27,500,000 Americans live on farms. This means that about 77 per cent are urbanites, and that consequently nearly three-fourths of the gasoline tax comes from residents of towns and cities. While they do not begrudge the expenditure of money on country roads, they are becoming clamorous for a higher percentage of expenditure on roads near the towns and cities. Their next cry will be for a considerable expenditure of gasoline tax money on city thoroughfares.

Last year about 10 per cent of the motor cars were scrapped. This year the percentage may be higher, but if you take 10 per cent of the new cost of the average car, you will have about $80 a year depreciation, exclusive of repairs, as contrasted with about $100 paid for gasoline including the $15 tax. By the side of these figures above (to say nothing of tires, repairs, garage expense and interest) the present gasoline tax shrinks to small proportions. A 4-ct. tax would be $20 a year per car, which is little enough when consideration is given to what it can buy in the way of added comfort and reduced wear and tear on steel, rubber and nerves.

"Needlessly Ugly Highways"

The title of a recent editorial article in The Saturday Evening Post is "Needlessly Ugly Highways." A quotation will serve to indicate the nature of the criticism.

"Road building has been elevated to the rank of a science, but it cannot yet claim, in any broad sense, to be numbered among the fine arts. We are still in the grip of the past and think of highways as purely utilitarian devices whose sole function is to enable us to get from place to place in the shortest possible time. We laymen, like our highway engineers, seemingly ignore the fact that our main-traveled roads, which were once used almost exclusively for necessary travel and for the transportation of goods, have now become

the playgrounds of leisure hours, the avenues along which we take our rest, pleasure and recreation in motor cars.

"We sally forth in quest of charm, restfulness and beauty, and presently find ourselves upon a hard, smooth ribbon of concrete or cement, straight as the ruler which laid it out. Ahead, we see nothing but the slowly converging, straight lines of the roadsides, which are finally lost at a hazy vanishing point. If we look a little to right or left, billboards come within the field of vision. We lose all sense of being in the open, for our setting has made us a part of a diagram illustrative of simple perspective. We have, to be sure, the road surface we paid for, but we have been cheated out of all the charm and beauty we might have had along with it had there been proper tree planting and an easily arranged succession of pleasant prospects."

Stated technically, the criticism is that our roads have been located like railroads, with long tangents and easy grades, but with no landscape architecture. And the plea is made that hereafter landscape architects be employed to assist highway engineers. "Landscape architects worthy of the name know how to break up straight lines and how to secure charming effects with the smallest sacrifice of increased distance."

The critic evidently had in mind the sinuous roads and the beautiful vistas that are so often found in city parks. But the highway engineer is usually prevented from giving desired curvature because rights of way are along section lines or other straight property lines. In many localities any effort to secure even slight changes in existing rights of way results in a storm of protest; and since the protestants are, in the final analysis, the employers of the highway engineers, it often amounts to handing in a resignation when an engineer ignores the protests.

The editor recalls many a bitter wrangle with property owners in the attempt to change the routes of existing highways. Even where it was obvious that the gradients were too steep, and could easily be remedied, it was rare indeed that a farmer would consent to a change of alignment. Had the argument in favor of a change been based solely on the added beauty of the route, the engineer would have been regarded as fit only for an asylum.

While agreeing heartily with the critic as to the desirability of more artistry in highway location and adjacent landscaping, we wish to point out that the educational program intended to bring this about should include a course of art for the farmers whose property must be secured before existing alignments can be changed. Highway engineers have opportunities to locate relatively few roads where farmer opposition to change is not a factor.

Most of our country where the ugly roads exist is a checkerboard of farms, highways follow fence lines, houses and trees parallel those lines, and the whole is anything but the work of a landscape architect. The highway engineer is commonly employed to "improve" the existing highway, which means to grade, drain and pave it. At present he has about as much chance of showing any artistic ability in the doing of it as a city engineer has in improving a street. This is probably all wrong. Doubtless the highway engineer should be given a free hand either to demonstrate his own ability as a landscape architect, or to employ such an architect; but no such freedom now exists, nor seems likely to exist until the general public becomes much more insistent upon having beautiful roads.

Where highway engineers have had the opportunity to lay out picturesque roads, as in our national parks, they have shown a high order of artistic talent. Because engineers are trained in science and in the use of instruments of precision, the popular conception is that they are deficient in artistic sense, although it would be hard to find any evidence that either mathematical precision or science is inimical to art. We make no claim, however, that landscape architects could not be employed with profit in beautifying our highways. What we object to is the implication that highway engineers are responsible for our ugly roads.

The point is well taken by The Saturday Evening Post that our highways have reached the stage of development where many of them should be regarded as if they were pleasure driveways. This conception was well presented in a recent editorial article in the Los Angeles Times. It was urged that there should be a continuous highway along the California coast. Many miles of beautiful coast highway already exist in California, and this has whetted the appetite of motorists for "more of the same." That editorial article closes thus:

"When the time comes that a motorist may drive for a thousand miles with the salt air in his nostrils and the flounces of surf by the roadside, there will be nothing like it in all the world. The Pacific Ocean is not the smallest asset of California."

All that will remain then will be to extend that highway in both directions, southward to Cape Horn and northward to Cape Romanzof—an addition of a mere 10,000 miles. But the day will surely come when tourists will travel the entire Pacific coast of North and South America over paved roads, with the ocean's roar never long beyond ear-range.

Let us begin now to entertain such visions and the realization of them will come sooner than we dream.

Pestiferous Speed Signs

On several recent long automobile trips the editor took pains to count the number of drivers who were observing speed signs that limited the velocity to 15 miles an hour. The number so counted was exactly nil. Nor was the number much greater of those who obeyed the 20-mile signs.

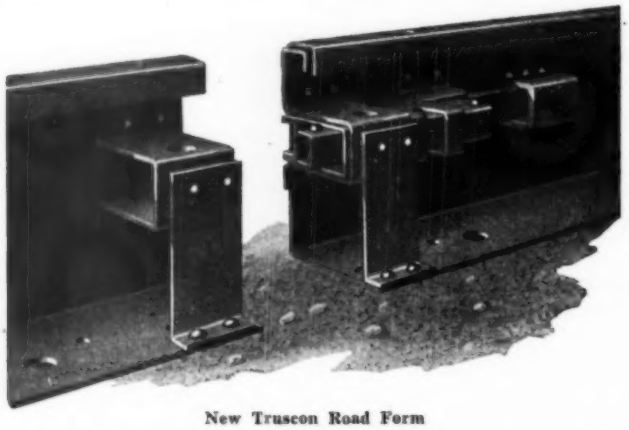
At street crossings, a 15-mile limit is rarely, if ever, needed; a 20-mile limit is often questionable. At other places on a street the limit need not be less than 25 miles an hour. All of this the motorist knows, and, knowing, acts accordingly. So rarely is any attempt made to enforce ordinances relative to very low speeds, that they are virtually dead letters. They should be amended and the speed signs repainted.

W. P. Gillette

Truscon Announces New Road Form

A new steel road form to which joint locks and other built-up parts are attached by 3/16 in. hot-driven rivets is being manufactured by the Truscon Steel Company of Youngstown, Ohio.

The manufacturers point out that contractors using forms with rivet attached joint locks and other parts easily and quickly replace broken or damaged parts on the job without special equipment. Either bolts or rivets may be used in making such repairs. Hot-driven rivets never loosen from use.



New Truscon Road Form

The new forms are completely interchangeable, each form is equipped with a male element on the adjacent end of the next form, thus making true alignment of joints always certain. A 7-in. sliding member is driven through keyways on each two adjoining forms and is held by two stakes to form a rigid joint.

The stakes are each 3½ in. from the joint, giving double support where it is most needed. Other stakes may be used wherever necessary between joints. Crooked stakes cannot throw forms out of alignment at joints.

The forms are stamped from 3/16 in. steel by a special machine weighing 100 tons, all bending of the steel being accomplished in one operation on one die. This makes all forms absolutely uniform and is said to be a distinct improvement over the older method of forming angles by successive stampings, which, due to slight variations in the carbon content and thickness of the metal, resulted in differences in the angles produced and consequent imperfect alignment of forms.

The new forms will take bends of 100 ft. radius, which is said to be 150 ft. shorter radius than is required in standard specifications for the use of steel forms. The short radius is obtained by the short locking apparatus at the joints, a special feature of the Truscon form.

Another outstanding point of the new forms is that they can be combined with any other Truscon form, even the first ones manufactured by the company. Forms of different heights can be joined to give perfect alignment and joints of positive rigidity.

Because of the uniformity of Truscon forms resulting from the method of their manufacture, it is contended that roads built with them will be relatively free from waves and irregularities, moreover, the distinct shape of the top rail of the Truscon form permits the finishing machine to rest on the inside wall of the form rather than on the outside edge of the head, thus saving 2½ per cent or more of the concrete.

The new forms are built to withstand hard usage, and are recommended as being distinctly economical from the standpoints of both first cost and length of service.

New and Improved Stroud Elevating Grader is Announced

A new and improved Stroud Heavy Duty elevating grader using a 42 in. belt has just been placed on the market, according to J. D. Adams Company of Indianapolis, who are exclusive sales agents in the United States and Canada for Stroud elevating graders and Little Red Dump Wagons.

A number of improvements have been made throughout the machine which add to its strength, durability and general efficiency; the major improvements are a power take-off feature, a new design carrier, and a new, all steel tongue.

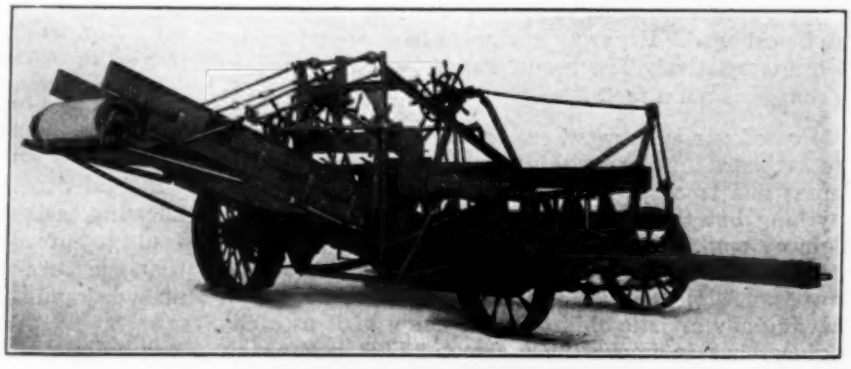
The power take-off is furnished as an extra, the grader being equipped regularly to drive the carrier from the rear axle in the usual way. The power take-off, of course, provides for driving the carrier, with power taken directly from the tractor and transmitted to the carrier by a flexible drive shaft and chain driving mechanism at the center of the grader. This mechanism is readily put on and utilizes the carrier chain which is transferred to the front side of the carrier.

In the operation of elevating graders the repair and replacement of damaged belts has always been a considerable item and any improvements which will reduce belt damage and prolong belt life will be heartily acclaimed by all elevating grader users. It is claimed by the manufacturers that in designing the new Stroud carrier absolutely nothing has been left undone to prolong belt life. The carrier construction is extremely simple and is sturdy and rigid so that the belt will always run true on the carrier. It is said that this carrier is fully 10 per cent stronger against warping and mis-alignment than any carrier heretofore produced by them.

Carrier sills are of heavy Z-bar steel. The carrier roller boxes are mounted inside and underneath the Z-bar sills so as to be fully protected from dirt. The carrier is so designed that edges of the belt cannot scrape the flareboard brackets.

As further protection to the belt a third idler roller has been placed underneath the carrier near the drum to prevent the belt sagging. A long steel shoe placed underneath the drum (a new feature) prevents drum coming in contact with wagon or trucks. At the lower end the belt is well protected by guards which prevent stones and roots from catching between the belt and the flareboards. A box-like shield prevents dirt being scraped into the upper pan or cathole.

Other improvements include a wider range of adjustment for the carrier, improved plow features, more convenient operation, and greater strength throughout. The distinctive Stroud



Improved Stroud Elevating Grader

frame design, which combines flexibility with strength is retained in the new machine.

With 3 ft. carrier extension furnished as regular equipment, this new model weighs approximately 13,500 lb. A folder describing this new machine will gradly be mailed to those addressing J. D. Adams Company, Indianapolis, Ind.

A New Power Hoist

The Hughes-Keenan Company of Mansfield, Ohio, manufacturers of dump bodies, hoists and a dirt moving unit, the Iron Mule, offers a new line of 1 to 7½ ton capacity power hoists. It is made in 3 sizes. A 1 to 2 ton capacity which is mountable on Ford, Chevrolet and other light trucks, a 3 to 5 ton size which is mountable on a variety of 2 to 3 ton trucks, and a 5 to 7½ tons capacity mountable on trucks of over 3 tons.

Its mechanism is simple and positive. Parts are few and rugged. Power is taken direct from engine shaft and transmitted to hoist ram through a train of three gears which are so arranged that coasting is impossible. With engine running at 850 to 1,000 r.p.m. the smallest model of this powerful hoist dumps a 2-ton load in approximately 15 seconds. The larger model will dump a load of 7½ tons in 25 seconds.

A dumping angle of 50 degrees eliminates need of body shaking to clear load and design permits body and load, when necessary, to be held at any point between loading position and the 50 degree dumping angle.

The specially designed clutch has large bearing faces and direct action throw-out at up and down positions. This automatic clutch action eliminates all need of reversing levers, thereby making hoist fool-proof and definitely eliminating chance of serious and costly breakdowns.

Another strong and exclusive feature is, that power is applied ahead of center of gravity. This assures dumping speed without undue strain on body, chassis or moving parts of the hoist. The hoist proper is suspended at three points and automatically equalizes itself regardless of trucks' position when dumping, so that no undue strain falls on hoist mechanism.

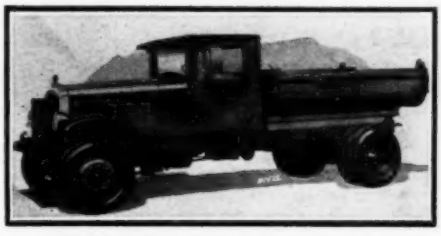
Detail of Hoist and Lifting Arms of New Hughes-Keenan Hoists

New Indiana Model 627AW Road Builder

Among the complete line of Indiana Road Builder models, appears the new model 627AW, 6-cylinder chassis, which carriers a rating of 20,000 lb. permissible maximum gross weight allowable.

The wheelbase of this new model is 156¼ in. with length back of driver's seat of 8 ft. 4 in. The engine is a Wisconsin Model "H," valve-in-head type, 6 cylinder, 4 in. bore and 5 in. stroke, with piston displacement of 377 cu. in., and developing 72 h.p. at only 2,000 r.p.m.

A full floating type, double reduction gear drive rear axle is used, with mechanical service brakes on the rear wheels of the internal expanding type, operating in brake drums by a vacuum booster, affording maximum braking facilities and very smooth operation. These brakes are 18 in. in diameter with 4 in. bands. Emergency brake is operated by hand lever, this being a 14 in. diameter disc brake mounted on propeller shaft.



Model 627AW, Six-Cylinder Indiana Road Builder

The frame is a special heat treated, pressed steel stock with a breaking strength of 90,000 lb. to the square inch. Transmission is of the unit power plant type, with five speeds forward and two in reverse—standard is with fifth in direct, optional direct on 4th speed with 5th speed an overdrive.

The Indiana patented "Tors-Elim" 3-point suspension mounting of motor, radiator and cab (exclusive to Indiana trucks) is used on this new model Indiana Road Builder.

The dump body equipment recommended for this model is an 81 cu. ft. steel dump body with straight sides and round bottom (square corners optional) with double acting tail gate and center partition for batch work. Width of body 72 in., standard length 102 in., height 19 in.

This new model is already much in demand with large contractors, road builders, and state and county highway commissions throughout the country, and is on a large production basis at the Indiana Truck Corporation's plant, Marion, Indiana.

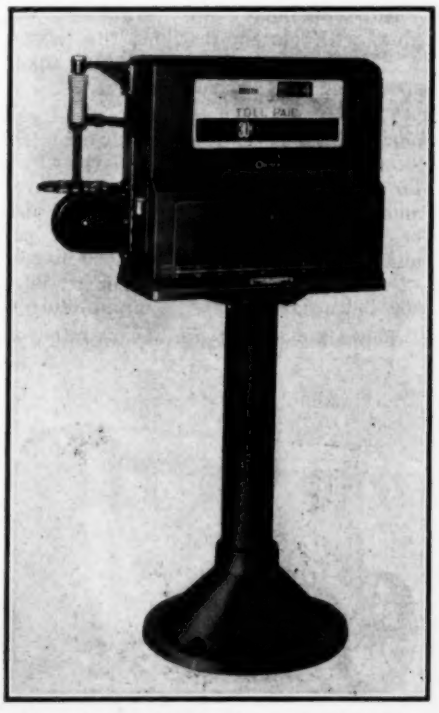
The New Ohmer Toll Bridge Register

A new product of the Ohmer Fare Register Company is an indicating and printing fare register which has been developed especially for use on toll bridges. This device is the result of a careful study of existing methods of collecting tolls through the cooperation of the owners and operators of several of the largest toll bridges in the country. It is a practical, economical and rapid system for this type of service. Traffic tie ups during rush hours will be largely eliminated and every toll will be indicated and recorded as to its exact amount and class in the presence of the traveler.

From the printed record which is removed from the register each day can be determined the total number of collections made, the total number of each class of traffic units crossing the bridge during any one hour period, or for the full day or shift, and a complete reckoning of the total amount of money or tickets for which each collector is responsible.

The new Ohmer toll bridge register is weather proof. Movable parts are so protected from the weather that dampness and corrosion are not to be feared.

The register is self contained in a single unit, ready to be placed at the collecting point and put in operation immediately on its delivery from the factory. With this register the amount paid is indicated and registered in an instant with one hand and change made with the other without requiring this operator to take a single step away from his position at the collecting point.



Ohmer's New Machine for Registering Toll Bridge Fares

C. H. & E. 1929 Model Triplex Road Pump

The C. H. & E. Manufacturing Co., Inc., Milwaukee, Wis., has greatly improved their No. 11 triplex road pump. The most important features are Texrope drive, drop forged crankshaft, roller bearings, steel gears enclosed and running in oil, and easily accessible valves.

The Texrope drive is a simple, clean, silent, positive and economical drive consisting of sheaves and twelve V-shaped Texrope belts. The power is transmitted by the wedging contact between these belts and the V-shaped groove in the sheaves. This drive is very smooth running, eliminating all back-lash which is so common in a gear reduction. Moisture, dust and dirt do not affect it. It is almost beyond the range of possibility for the drive to fail and shut down the pump, it is claimed.

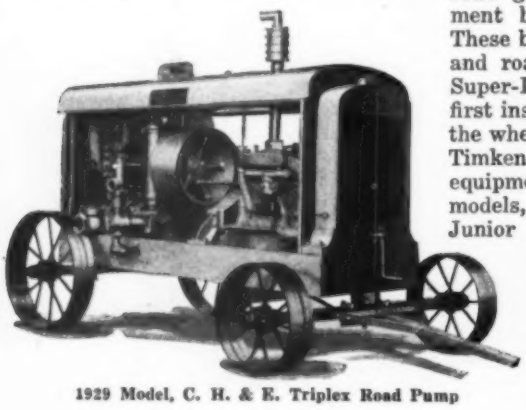
The crankshaft is drop forged. It is of ample size to conform with the balance of this sturdy, dependable outfit. Roller bearings are used for the crankshaft and countershaft, and eliminate undue friction and loss of power. They insure long life without replacement.

The gears are steel, machine cut, wide face, enclosed and running in oil. The water box, suction and discharge valve manifolds are cast in one piece. Special metal valves which will not warp or corrode are used, and are easily accessible. Each valve has an individual cover, held down by a clamp. The cover can be readily removed by loosening one nut. The plungers are outside packed, and easily adjusted or repacked.

A 35 hp. heavy duty Waukesha engine, with clutch, provides the power. A slotted frame allows the taking up of stretch in the Texrope drive.

This outfit has a capacity of 80 gal. per minute, maximum pressure of 500 lb of equivalent head of 1,157 ft., which provides ample water for a road paver and necessary sprinkling. It can also be furnished to deliver 100 gal. per minute, maximum pressure 400 lb., or 125 gal. per minute, maximum pressure 300 lb., according to the manufacturer.

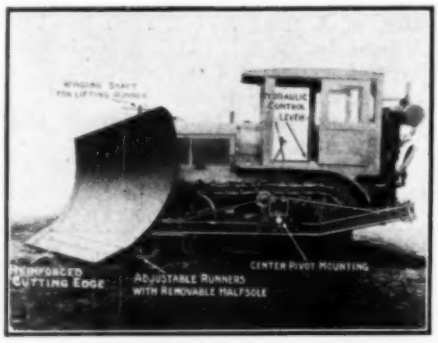
The complete machine is mounted on a welded steel truck frame, and wide faced steel wheels. It is totally enclosed with steel house, which can be locked. This outfit is fully equipped with all discharge fittings and pressure gauge, ready to operate.



1929 Model, C. H. & E. Triplex Road Pump

One-Man Snow Plow Developed by LaPlant-Choate

A strictly one-man snow plow designed for crawler type tractors has been developed by La Plante-Choate. The plow is hydraulic controlled by a lever conveniently located near the tractor controls.



LaPlant-Choate Snow Plow

The moldboard has considerable overhang, which prevents snow from falling back into the path of the tractor. This overhang is also effectively used in nudging over side banks. Two adjustable runners have been attached to the frame in order that the plow may be used without pressure on the cylinder. The winding shafts for adjusting these runners are located well above the tracks, thus making it easy to regulate the cutting depth.

The plow is closely built around the tractor, it is an ideal unit to be loaded on a truck or trailer for hauling to operations needing immediate attention.

Roller Bearings on New Russell Graders

Heavy duty Timken roller bearings are now standard equipment on Russell road graders, according to announcement by the Caterpillar Tractor Co. These bearings support the worm gears and road wheels of the latest Russell Super-Reliance graders. This is the first instance of their use other than on the wheels of road graders, it is claimed. Timken bearings are now standard equipment for wheels on all Russell models, except Standard No. 1 and Junior graders. Reduction of end thrust and spindle friction are thus gained in all these models. Bearings lengthen the life of the grader and reduce the power required for pulling, thus decreasing road expense and, consequently, the taxes the taxpayers bear. And the operator's work is easier.

The Caterpillar Tractor Company of San Leandro, Calif., who are now making and handling the Russell line of graders, will gladly furnish more information.

New Willamette Hoist for Caterpillar

Many jobs and tasks too small to warrant the use of a Caterpillar Thirty and hoist can now be economically done by the 2-ton equipped with a Willamette hoist.

The hoist for the 2-ton embodies all the features contained in the larger models. It is a compact, self-contained, single drum, single speed hoist which attaches to the rear of the tractor underneath the tractor seat.

The brake will hold any load within the capacity of the hoist. A cone friction clutch and a locking ratchet are primary parts. Total overhang from the back of the tractor transmission case is but 21½ in., which so distributes hoist weight that the tractor is not unbalanced, and the hoist does not interfere with the drawbar of the tractor. An outboard gypsy for snubbing is also included as standard equipment.

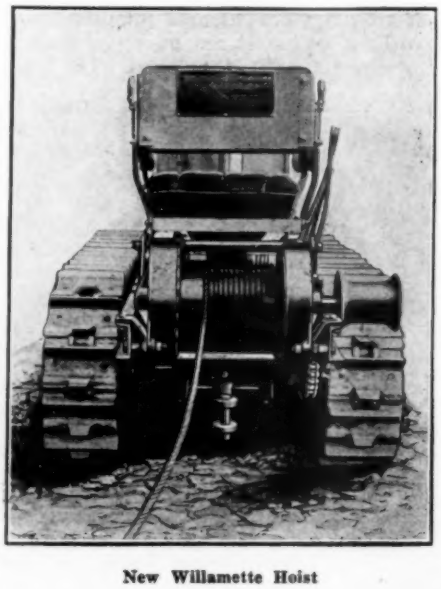
Specifications

(Stated by manufacturer)

Capacities:
- Cable capacities ..... 600 ft. ⅝ in. line
  400 ft. 7/16 in. line
- Line speeds, average ..... 240 ft. per min.
- Line pull ..... 3,500 lb. bare drum
  1,600 lb. full drum

Drum:
- Barrel, 5-in. diameter. Flanges, 12½ in. diameter.
- Length of barrel, 12½ in.

Weight:
- Approximately 400 lb. without cable.



New Willamette Hoist